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NATO RESEARCH STUDY GROUP ON PATTERN RECOGNITION.(U)

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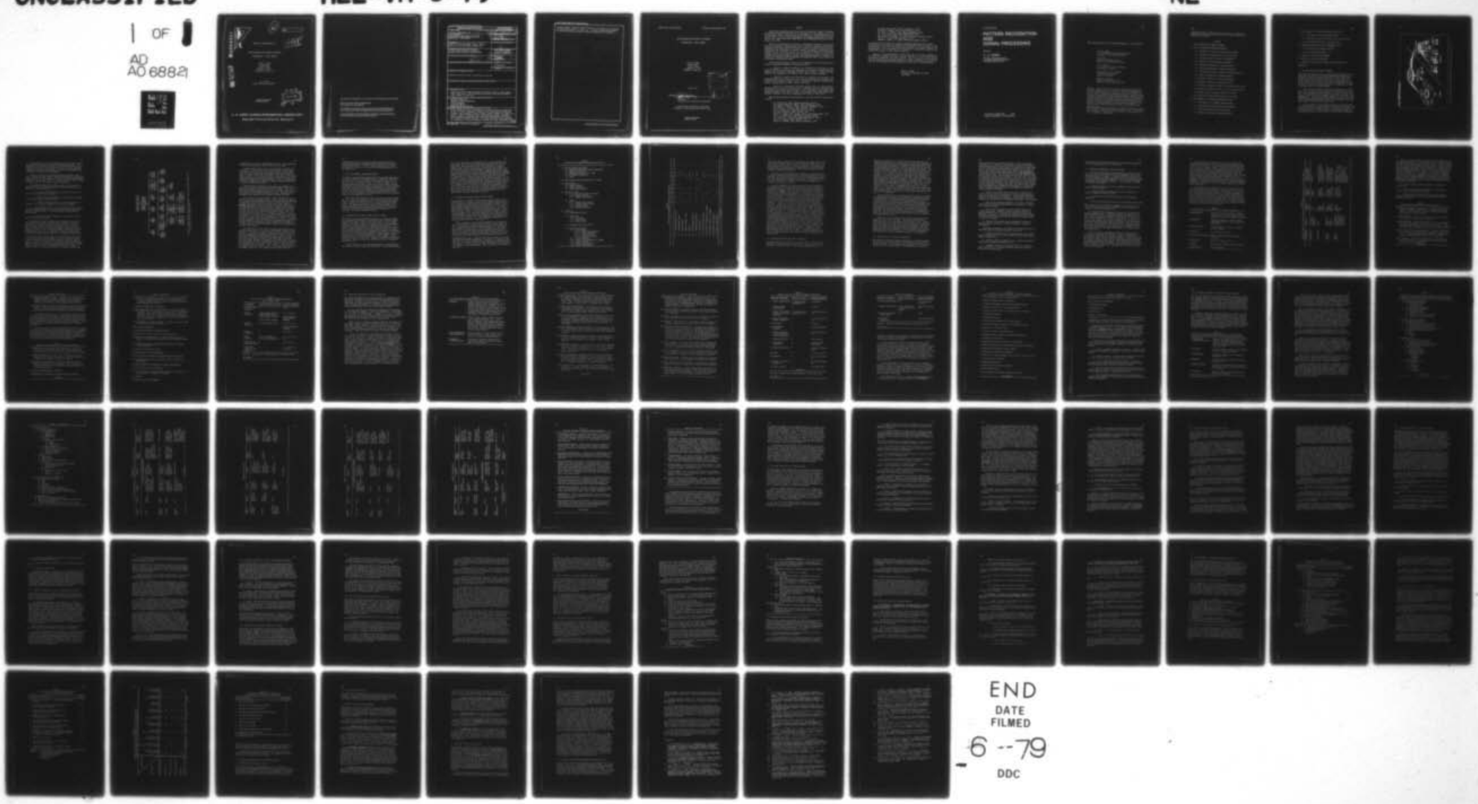

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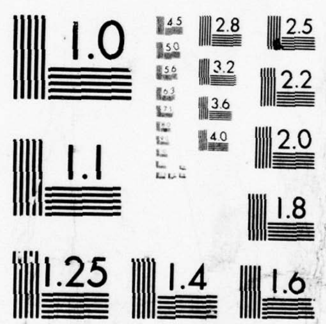

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Technical Memorandum 5-79

NATO RESEARCH STUDY GROUP ON PATTERN RECOGNITION: FINAL REPORT

David C. Hodge
Bruno Beek
John S. Dehne
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Heywood E. Webb, Jr.

April 1979
AMCMS Code 611102.74A0011

U. S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

AC/243 (Panel III) RSG-4 on Automatic Pattern Recognition was established in 1971 to promote information exchange on military pattern recognition projects, and to identify topics of mutual concern suitable for cooperative research. RSG-4 developed a topical classification scheme, exchanged project summaries, performed three technology assessments, and initiated two cooperative research programs. This paper describes NATO organization for cooperation on military problems, surveys the current cooperative (contd)

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research efforts, notes the group's failures, and touches on the prospects for future NATO activity in this area. Previously unpublished analyses of military problems in automatic pattern recognition are included.

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PREFACE

This report summarizes the activities of NATO AC/243 (Panel III) RSG-4 on Automatic Pattern Recognition from November 1971 to January 1978. An invited paper based on this report was presented to NATO Advanced Study Institute No. 78/33 on Pattern Recognition and Signal Processing, which was held at the École Nationale Supérieure des Télécommunications, Paris, France, June 1978.

RSG-4 was established to promote information exchange on military pattern recognition applications, and to identify topics suitable for cooperative research. RSG-4 developed a topical classification scheme, conducted three iterations of project summary exchanges, performed three assessments of the state of the art in pattern recognition technology (image, speech, and mechanical wave processing), and initiated two cooperative research programs (images, and speech processing). Cooperative research on mechanical wave processing was proposed, both in the sonar and battlefield surveillance areas.

At this writing (March 1979), three NATO RSG's are continuing the research programs developed or proposed by RSG-4:

RSG-9 on Image Processing is conducting programs on the classification of military and geographical targets in multispectral imagery. The Principal US Delegate to RSG-9 is Mr. John S. Dehne, US Army Night Vision Laboratory, Fort Belvoir, VA 22060, Autovon 354-5745.

RSG-10 on Speech Processing is conducting research on connected-word voice data entry for military command and control. The Principal US Delegate to RSG-10 is Dr. Bruno Beek, Rome Air Development Center, Griffiss AFB, NY 13441, Autovon 587-3454.

RSG-11 on Automatic Pattern Recognition in Battlefield Surveillance held its first meeting in February 1979 and is presently developing and exchanging data bases. The Principal US Delegate (and Chairman Pro Tem) is Mr. Bob O. Benn, USA Engineer Waterways Experiment Station, Vicksburg, MI 39180, Telephone (601) 636-3111, Ext. 2683.

The following personnel participated in the work of the US delegation to RSG-4:

Dr. Bruno Beek, RADC, Speech Processing, 1975-8
Dr. Sidney Berkowitz, NSRDC, Sonar Processing, 1977
CPT Ronald D. Bouvier, RADC, Alternate Delegate, 1973-5
Dr. William J. Condell, ONRL, Advisor, 1971
John S. Dehne, NVL, Image Processing, 1975-8
Dr. Fred Frishman, AERO, Advisor, 1971
Warren E. Grabau, WES, Images 1974-5; Mechanical Waves, 1977
Dr. D. C. Hodge, HEL, Principal Delegate, 1972-8
COL Russell B. Ives, ACDA, Mechanical Waves, 1975-8
LTC I. G. Kinnie, AERO, Advisor, 1971-3
Edward P. Newberg, NSA, Speech Processing, 1974

Dr. Hans Oestreicher, AMRL, Consultant, 1974-7
Bernard B. Scheps, ETL, Image Processing, 1974
Dr. Bryce L. Schrock, ETL, Image Processing, 1974
Dr. V. E. Shely, ETL, Image Processing, 1974
CPT Edward J. Simmons, Jr., RADC, Alternate Delegate, 1972-3
CDR A. E. Victor, ONRL, Observer, 1974
Heywood E. Webb, Jr., RADC, Alternate Delegate, 1975-8

In addition to the above, who actually attended RSG-4 meetings, inputs were received at one time or another from representatives of about 65 DoD organizations, six other government departments, and approximately 120 contractors. The assistance of these pattern recognition specialists contributed greatly to the success of RSG-4.

Lastly, the accomplishments of RSG-4 were due, in no small measure, to the generous support received from the Director of the US Army Human Engineering Laboratory, Dr. John D. Weisz. Not the least of this support was his allowing the principal delegate to devote a substantial portion of his time to managing the NATO cooperative effort over a six-year period.

DAVID C. HODGE
Principal US Delegate to RSG-4
1972-1978

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NATO RESEARCH STUDY GROUP ON PATTERN RECOGNITION: FINAL REPORT*

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ABSTRACT. AC/243 (Panel III) RSG-4 on Automatic Pattern Recognition was established in 1971 to promote information exchange on military pattern recognition projects, and to identify topics of mutual concern suitable for cooperative research. RSG-4 developed a topical classification scheme, exchanged project summaries, performed three technology assessments, and initiated two cooperative research programs. This paper describes NATO organization for cooperation on military problems, reviews RSG-4 activities and summarizes its accomplishments, surveys the current cooperative research efforts, notes the group's failures, and touches on the

*The views expressed in this paper are those of the authors, and do not necessarily reflect the official position of the U. S. Department of Defense. Reproduction of this paper for any purpose of the U. S. Government is authorized.

prospects for future NATO activity in this area. Previously unpublished analyses of military problems in automatic pattern recognition are included.

OUTLINE

1. NATO COOPERATION ON DEFENSE RESEARCH

2. RSG-4 ON AUTOMATIC PATTERN RECOGNITION

   2.1 Development of a topical classification scheme

   2.2 Information exchange about national programs

   2.3 Selecting potential topics for cooperation

   2.4 Planning for the technology assessments

   2.5 Technology assessment of image processing

   2.6 Technology assessment of speech recognition

   2.7 Technology assessment of mechanical wave processing

   2.8 Proposed cooperation on image processing

   2.9 Proposed cooperation on speech processing

   2.10 Proposed cooperation on mechanical waves

   2.11 Proposed cooperation on APR in battlefield surveillance

   2.12 Proposed cooperation on APR in sonar signal processing

   2.13 Summary note on proposed cooperative research

   2.14 Search for other military APR topics for study

3. RSG-4 SUBGROUP 1 ON IMAGE PROCESSING (NOW RSG-9)

   3.1 Development of an imagery transfer format

   3.2 Documentation of image processing algorithms

   3.3 Assessing national military priorities

   3.4 Cooperative research on image processing

1. NATO COOPERATION ON DEFENSE RESEARCH

This paper presents a review of the mechanisms of cooperation that exist under the umbrella provided by the North Atlantic Treaty Organization (NATO) and, more specifically, it is a final report on the activities on one NATO group, viz., AC/243 (Panel III) Research Study Group 4 (RSG-4) on Automatic Pattern Recognition. At the outset it will be useful to consider the general structure of NATO and review the various aspects of its activities in scientific cooperation on military problems.

Figure 1 shows an overall, simplified organizational chart of NATO. The main point here is that NATO is divided into two separate parts immediately below the level of the North Atlantic Council. One part consists of the civil side of NATO; the other is the military side. The military side is composed of the Military Committee and its supporting International Military Staff, with three major allied defense commands. The Military Committee advises the North Atlantic Council on military matters.

From this point on, our discussions will be concerned exclusively with activities taking place on the civil side of NATO. The civil side functions through a number of Committees, some of which are shown in Figure 1. There also is an International Staff to provide support for the North Atlantic Council and its Committees.

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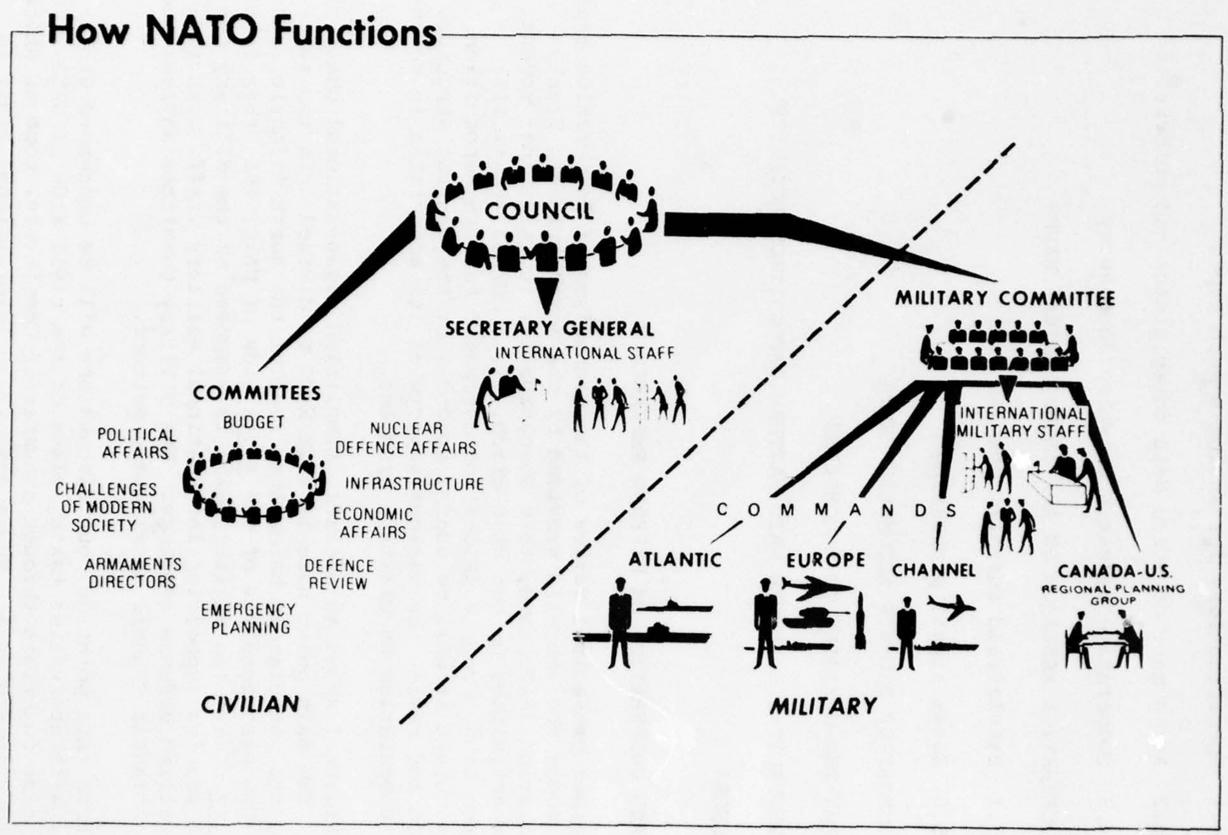

Figure 1. Simplified NATO organizational chart. (From Annex A to Ref. 1.)

The Conference of National Armaments Directors (CNAD), AC/259, was established in 1966 to replace the Armaments Committee. The CNAD and its subordinate bodies have been given Terms of Reference (TOR) laid down by the North Atlantic Council which are directed toward the promotion of cooperation in research, development, and production of future military equipment.

Figure 2 shows how the CNAD is organized to promote cooperation. There are Groups, Panels, Research Study Groups and Subgroups. Directly below the CNAD there are six bodies which are collectively referred to as the "Main Groups". (There also are six other, smaller groups, not shown, having more restricted missions.)

The Defense Research Group (DRG), AD/243, is the body under which the pattern recognition cooperation has been conducted. The functions of the DRG are to [1]:

a. Exchange information on new research and technology which might lead to future equipment.

b. Review the possible military consequences of advances in the field of science and technology.

c. Identify suitable areas or individual projects for bilateral or multilateral cooperation in defense research.

d. Undertake studies, at the request of any of the three service armaments groups, in fields where requirements cannot be met until a breakthrough or a serious advance in technology has been achieved.

e. Cooperate fully and maintain close liaison with the other Main Groups of the CNAD.

The work of the DRG is conducted by a number of Panels which are constituted to address specific topics related to military applications. Note that there is no Panel II or VI. Panels, as well as lesser bodies, are created by the DRG whenever a need arises. They are given a name and assigned a non-recurring number. They function for as long as they are needed, and finally they are disbanded when their work is completed. The pattern recognition activity was organized under Panel III on Physics and Electronics.

The functions of AC/243 Panel III are essentially the same as those of the DRG (see above) except, of course, they are limited to topics in physics and electronics related to military applications. The work of the Panels is conducted by Research Study Groups (RSGs), as well as by Ad Hoc Groups and Exploratory Groups. These latter two types of groups are established on special topics to provide a means of gathering specialists to discuss a subject and

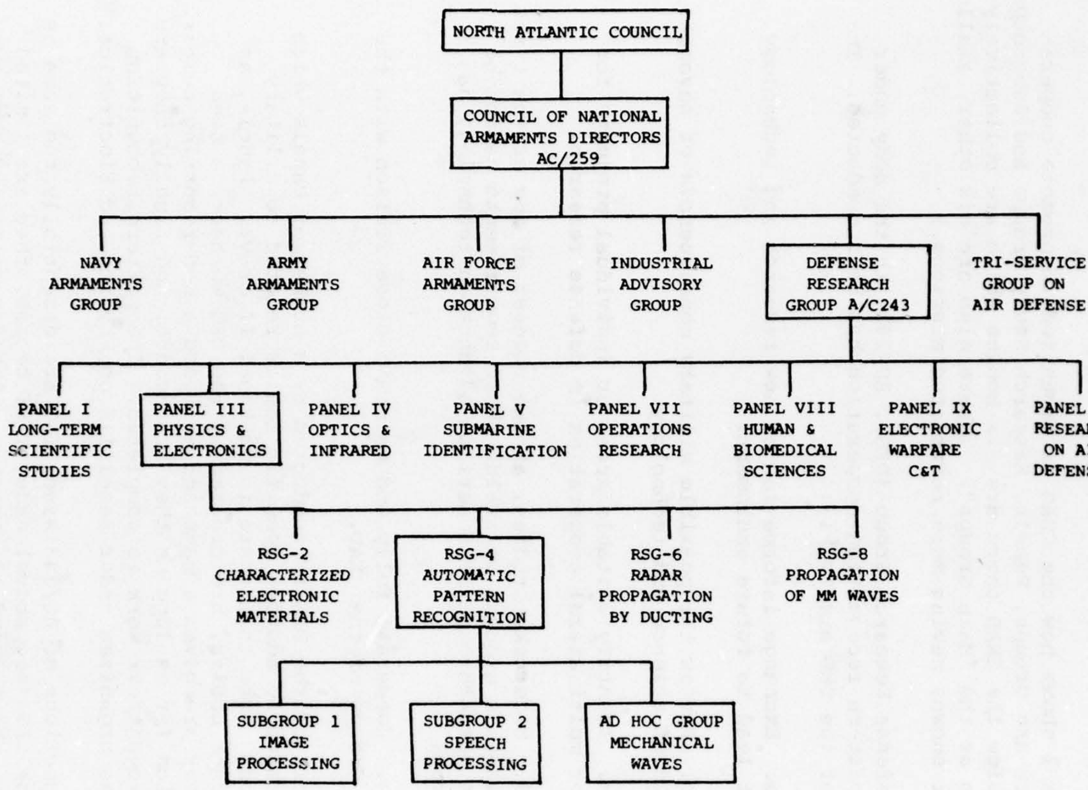

Figure 2. Organizational chart of the CNAD AC/259, DRG AC/243, Panel III, and RSG-4. (As of December 1977.)

recommend for or against establishment of a RSG. Such groups have a very limited life span, often not more than one year.

Research Study Groups (RSGs) are constituted to exchange information on a specific topic of military interest, and to identify projects for potential cooperative research and development. RSGs are usually charged with developing a TOR that is narrow in scope, and RSGs' life spans are normally on the order of five years. Sometimes RSGs are established to pursue cooperative research that has been recommended by another NATO body. In rare circumstances a RSG may be permitted to establish Subgroups and/or Ad Hoc Groups to deal with specific sub-topics.

Referring again to Figure 2, note that as of December 1977 Panel III on Physics and Electronics had four RSGs. There are also several Exploratory Groups not listed in the figure. Also note that RSG-4 on Pattern Recognition is one of the rare RSGs that has been permitted to establish subordinate groups. When RSG-4 was disbanded these Subgroups were elevated to become full RSGs.

In concluding this brief review of NATO organization for cooperation, two points should be made. First, the types of cooperative research and standardization activity conducted under NATO and, in particular, under the DRG, are mainly activities related to military applications; they are also activities for which there is *no other* appropriate forum or mechanism. The NATO treaty and administrative umbrella provide a means for cooperating on problems for which other (civil) mechanisms are inappropriate. This does not mean that all of the work is classified; in fact, most of it is unclassified and some of it is ultimately published in the open literature. But the NATO umbrella provides a forum for discussing sensitive military topics at a preliminary level without the necessity for completely open circulation of data or results. Conversely, the NATO umbrella is not used to conduct information exchanges or research for which appropriate forums and mechanisms already exist. In other words, if you can do under the IEEE or at the IJCPR you do not need a NATO group.

The second point is that there are two general methods of initiating a NATO study of a scientific topic related to military applications. One way is for one or more nations to petition a Panel directly, through their Delegates, expressing interest in some topic and recommending establishment of a RSG. That is the way in which RSG-4 on Pattern Recognition was established (see below). The other common approach is for another RSG (under Panel III) or some other Panel or body to recommend a topic for study. Frequently, such recommendations result from studies conducted by AC/243 Panel I on Long Term Scientific Studies (see Figure 2). Some time ago, for example, Panel I conducted a study on "Fighting Under Conditions of Limited Visibility". As a result of that study, Panel III

established an Ad Hoc Study Group on Military Applications of Millimeter Waves which conducted further discussions, and recommended establishment of a RSG on certain aspects of this topic. As indicated in Figure 2, such an RSG was established and is now functiohing [2].

2. RSG-4 ON AUTOMATIC PATTERN RECOGNITION

In 1967 the United Kingdom suggested that the military applications of pattern recognition technology might be suitable as the topic for a RSG, but there was insufficient interest at that time. In 1970 the topic was suggested again, this time by Germany. An exploratory meeting was held in June 1970 at which Canada, Germany, Netherlands, and United Kingdom were represented. It was concluded that there was a basis for further discussions, and that speech recognition should be kept separate from automatic pattern recognition. In July 1970 these conclusions were reported to AC/243 Panel III and, subsequently, the establishment of an RSG on Pattern Recognition was approved by the DRG.

The constitutive meeting of RSG-4 was held in London in November 1971. Countries represented at the first meeting were Canada, France, Germany, Netherlands, Norway, United Kingdom and United States. Germany, as Pilot Nation, was selected to chair the RSG, and Dr.-Ing. Hermut Kazmierczak, from the Forschungsgruppe fur Informationsverarbeitung und Mustererkennung (part of the Gesellschaft zur Forderung der Astrophysikalischen Forschung E. V.), Karlsruhe, was elected Chairman of RSG-4.

2.1 Development of a topical classification scheme

RSG-4's first task was to develop a topical classification scheme for organizing the exchange of information about national pattern recognition programs. Table 1 shows the scheme that was finally adopted. Note that, despite the recommendation of the preliminary 1970 meeting, speech recognition appears in the breakdown. One reason why speech recognition was included undoubtedly was the fact that the Dutch Delegate to RSG-4 was a speech recognition expert! Another may have been that the technical visits held in conjunction with the first RSG-4 meeting included two organizations -- EMI, Ltd., and the National Physical Laboratories -- where automatic speech recognition was being investigated along with a number of other pattern recognition topics, e.g., character recognition, man-machine interaction, adaptive processing, feature extraction, fingerprint recognition, etc.

Another word about the unsuccessful attempt at dichotomizing the pattern recognition topic may be helpful. It now seems perfectly

clear (with the benefit of hindsight) that, at the time RSG-4 was constituted, Panel III was of the opinion that the terms "pattern recognition" and "image processing" were synonymous. In fact, comments made to this writer early in the work of RSG-4 made it very clear that Panel III was shocked to discover how broad a charter it has unknowingly given to RSG-4. Whereas RSGs are generally assigned relatively narrow topics and expected to be able to quickly organize them and select relevant military applications and problems for cooperation, in this case the assigned topic was very broad. Indeed, it very soon became apparent that there was interest (in one or more countries) in applying the developing PR technology to virtually all of the complicated military information-handling problems. Thus, whereas Panel III had hoped that RSG-4 would be able to define some topics for cooperation and complete the cooperative projects within five years, in fact it took RSG-4 nearly five years to define the topics and develop the cooperative research proposals. And now there are three RSGs that will each function for five or more years in pursuing cooperative projects!

2.2 Information exchange about national programs

Having agreed on a topical classification scheme (Table 1), the next step was to exchange as much national pattern recognition project information as possible so each participating nation would have as much background information as possible. To that end each participating country was asked to distribute to all the others descriptions of defense-supported programs related to all of the topics listed in Table 1. This first exchange of project information took place at the second RSG-4 meeting (June 1972). Each country prepared a set of project summaries that included information about the technical objectives, approach, recent progress, level of effort, funding, etc. The information exchanged was unclassified and unlimited in distribution.*

Table 2 presents a statistical breakdown of the PR projects that were reported as being pursued by the RSG-4 participants in 1972. Probably the two most informative parts of this table are the extreme right-hand column, and the bottom line. The right column shows the percentage of all the reported projects that relate to the various research and applications topics (Table 1). These data indicate that the largest number of projects was being conducted in the areas related to image processing (Topic 5.0),

*It may be of interest to determine how much information cannot be exchanged under these restrictions. From the U. S. position, less than 10% of PR project summaries were classified or had distribution limitations. Virtually all of the basic and applied research project summaries were exchangeable. Thus, practically no information was lost.

Table 1
Classification Scheme for APR Research Activity

- 1.0 General Methods and Theory
  - 1.1 General PR Theory and Allied Techniques
  - 1.2 Adaptive Processing
  - 1.3 Man-Machine Interaction in APR
  - 1.4 Situation Recognition
  - 1.5 Other
- 2.0 Non-Imaging Signals (Electrical, IR, Video)
- 3.0 Radar Signals
  - 3.1 Target Detection
  - 3.2 Target Tracking
  - 3.3 Target Classification
- 4.0 Acoustic Signals
  - 4.1 Sound, including Seismic and Sonar
    - 4.1.1 Target Detection
    - 4.1.2 Target Identification
  - 4.2 Speech
    - 4.2.1 Speaker Verification
    - 4.2.2 Speaker Identification
    - 4.2.3 Isolated Words
    - 4.2.4 Continuous Speech
- 5.0 Patterns
  - 5.1 Multichannel Signals
  - 5.2 Characters
    - 5.2.1 Multifont
    - 5.2.2 Hand Printed
    - 5.2.3 Hand Written
  - 5.3 Processing of Line Patterns
  - 5.4 Pictures and Scenes
    - 5.4.1 Preprocessing
      - 5.4.1.1 Image Digitalization
      - 5.4.1.2 Image Enhancement
      - 5.4.1.3 Image Filtering
      - 5.4.1.4 Feature Extraction
    - 5.4.2 List Processing
    - 5.4.3 Control and Navigation by Images
    - 5.4.4 Target Detection
    - 5.4.5 Target Classification
    - 5.4.6 Scene Interpretation

Table 2
1972 Project Breakdown by Subject and Country

		CA	FR	GE	NE	NO	UK	US	%
1.0	General Methods & Theory	1	5		1	1		25	19
2.0	Non-Imaging Signals	1	1	1	1	2		9	9
3.0	Radar Signals	2	1	5	1			7	9
4.1	Sound, Seismic, Sonar	1		2				5	
4.2	Speech	1	6	2	1		3	18	18
5.1	Multichannel Signals							3	
5.2	Character Recognition	1	4	3	6		5	8	15
5.3	Line Patterns				2	1	4		
5.4.1	Picture Preprocessing	5	3	2				10	11
5.4.3	Control & Navigation by Images		1	2		1		2	
5.4.4	Target Detection in Images	1						2	
5.4.5	Target Classification							2	
5.4.6	Scene Interpretation			1				1	
	Percentage	7	12	11	7	3	5	55	

the second largest number in general methods and theory (Topic 1.0), and the third largest number in speech processing (Topic 4.2). The bottom line indicates that, as might be expected, over half of the total number of projects was being conducted by the United States, and that France and Germany had the next largest number of pattern recognition projects in progress.

When all of the national project summaries had been circulated, the seven documents were combined into one and distributed to researchers in the participating countries for information and comment [3]. This exchange of PR project information was repeated in 1973 and 1976; the resulting compilations of national summaries are listed as References 4, 5 and 6.

Certain problems were recognized during the 1976 compilation and exchange of project summaries that should be kept in mind in future NATO exercises. These related to the difference between a collection of project (work unit) descriptions and a collection of laboratory or national work programs. (A "project" or work unit is the smallest separately-funded piece of research that is being done; a "program" is a collection of all the projects on a particular military topic.) In general, collections of project descriptions (unclassified and unlimited) can be obtained easily, even in the U. S., and exchanged relatively freely with other NATO countries. (In the U. S., such a collection can be obtained by accessing a computerized data base.) By contrast, the ability to compile a national work program, laboratory by laboratory, seems to vary inversely with the size of the country. Such a compilation is relatively easy for the smaller NATO countries, but nearly impossible for the U. S. (It could only be done by contacting each of the laboratories individually.) Also, while collections of project descriptions may easily be exchanged within the NATO community, a complete national work program description (for any military topic, including basic research) will, undoubtedly, be classified at least NATO RESTRICTED. Early in the work of RSG-4 the collections of project descriptions (upon which the Table 2 statistics were based) were entirely satisfactory. Later, as cooperation got underway and as we searched for additional military topics to assess, these collections became less useful. Managers of future NATO projects should keep this in mind: the broader the topic, the more difficult it will be to compile national program descriptions, and the less likely that they can be freely exchanged, even among friends.

2.3 Selecting potential topics for cooperation

Each NATO RSG has to formulate its own TOR, and to select the most appropriate mechanisms for accomplishing its goals, subject to the approval of its parent panel. Thus, having informed all of the

defense PR researchers in the participating countries about the current research projects, RSG-4 began to discuss ways and means of identifying the significant technology gaps that might form the basis for cooperative research. Initially, a survey letter was sent to each researcher and project monitor whose work was listed in the combined PR summary document [3]. Each addressee was asked to indicate: (i) his interests in PR or APR as related to the topics in Table 1; (ii) national projects about which more information was desired; (iii) projects he felt he could make a contribution to; and (iv) projects that seemed to be the most likely candidates to form the basis of cooperative research. The results of this survey were exchanged at the third RSG-4 meeting (November 1972). A very large number of international inquiries about PR projects resulted from this survey. In addition, curiously, at least in the U. S., there were a large number of intranational inquiries. In fact, several U. S. researchers stated that they had not previously been aware of other defense laboratories doing similar work, and one wag even suggested that we should start a cooperative research project among U. S. researchers!

Also discussed at the third meeting was the notion of organizing international workshops for the purpose of identifying topics for cooperation. These would have been conducted by inviting national specialists to talk about military applications of PR, highlighting the unsolved problems and gaps in our knowledge. Moreover, it was proposed that selected discussants could synthesize the presentations and arrive at a series of goals that could be translated into research proposals. Three possible topics for workshops were identified by RSG-4 and a fourth was suggested by Panel III: (i) picture and scene processing; (ii) APR applied to electronic warfare; (iii) speech understanding; and (iv) adaptive and interactive processing.

Interests in these workshop topics were surveyed, and other suggestions were also solicited. Some degree of interest was found for every one of the topics listed in Table 1 [7]. However, when these results were presented at the fourth meeting (May 1973), negative comments from Panel III were also presented. Apparently Panel III had had some bad experiences with workshops--too often they served only as a forum for discussing problems, and no recommended solutions were forthcoming. As a result RSG-4 abandonned the workshop as a means of identifying topics for cooperation.

2.4 Planning for the technology assessments

The alternative procedure adopted by RSG-4 was to devote a portion of each of its regular meetings to discussion of a specific military APR problem. This discussion was structured so it would ultimately result in the development of recommendations to Panel III

about directions for cooperative research. Since the national delegates were not expert in all possible military APR problems, these discussions were conducted with the assistance of specialists from countries having ongoing research programs on the particular topics. Specialists were, among other things, chosen because of their better than average understanding of the user requirements for APR applications. Each RSG-4 meeting was to be devoted to one specific topic, and it was anticipated that several meetings might be required to complete the assessment of any one topic. The topics to be selected for discussion were to be limited to those with definite military relevance; topics of interest only to civil researchers were therefore excluded. Each RSG-4 participant could send one or more specialists to discuss any topic, but each would be responsible for presenting an independent assessment of the technology. These independent assessments were to be prepared to answer the following specific questions:

a. What is the present state of the art in automatic processing (name of topic or application)? Specify military application(s) involved in your assessment. To what extent do present systems solve the problem, or part(s) of the problem? What programs are in existence aimed at developing solutions to the problem?

b. What are the unsolved problems? If possible, indicate which of these unsolved problems might form the basis for cooperative research programs.

c. What is the estimated cost (time, money, manyears) of solving the problem? (Assume an orderly program of basic and applied research, but no international cooperation beyond that presently in existence.) Estimate the savings which might result if cooperative research among the NATO countries could be brought to bear on the problem.

d. What are the probable system requirements (hardware, software, speed) necessary to solve the problem, or part(s) of the problem?

Technology assessments were ultimately conducted by RSG-4 on three APR topics of military relevance, as follows:

a. Automatic target detection, identification, and classification in image date (e.g., reconnaissance, picture-aided control, target following, etc.).

b. Automatic speech recognition (e.g., auditory man-machine communication, speaker verification, etc.).

c. Automatic processing of mechanical waves in solids, liquids, and gases (e.g., acoustic, seismic, and sonar target detection and classification).

The results of these three assessments are discussed and presented in the following Sections 2.5, 2.6 and 2.7.

2.5 Technology assessment of image processing

One of the things that had to be decided in conjunction with this, the first of the formal technology assessments, was in what format to present the results. This was a nontrivial point since it would ultimately influence the extent to which the results would be used by the military APR community, as well as the development of proposals for cooperative research. It was decided to attempt to construct four tables:

a. Military tasks that could be automated through the application of APR techniques.

b. Image processing techniques that must be perfected in order to automate the military tasks.

c. State of the art of both applications and processing techniques.

d. Unsolved problems associated with the processing techniques.

After these four tables had been developed, they would be circulated to national researchers for comment and for expressions of interest in cooperative research [8].

The image processing assessment was begun at the fifth RSG-4 meeting (November 1973). Independent assessments addressing the points listed in Section 2.4 were presented by Ian Henderson (Canada), Helmut Kazmierczak (Germany), R. Hoffman and E. J. Simmons (U. S.), B. B. Scheps (U. S.), and V. Shely and B. Schrock (U. S.). Military applications or problems represented in these independent assessments included remote sensing in general, hard target detection, and terrain analysis. The results of the technology assessment were circulated to national researchers for comment, and the formal report of the assessment was finalized at the seventh meeting (August 1974).

It was, of course, concluded by RSG-4 that image processing is a topic of high military relevance. Table 3 lists military tasks that we would like to be able to automate. While most of the participating countries are conducting research on image processing, the results to date indicate that the human operator cannot easily be replaced by automatic procedures. Some semi-automatic solutions might be feasible in the near future, and applying them to the tasks listed in Table 3 would result in improved efficiency of the military systems concerned.

RSG-4 noted in its assessment [9, 10] that present image processing technology is not able to cope with all imagery problems with equal facility. Some relatively straightforward problems, such as IR missile guidance, have been solved by small elegant PR hardware systems. At the other extreme lies the problem of locating targets in noisy backgrounds, such as terrain, in which there are few existing analytic capabilities. This wide range of potential applications is further exemplified by the problems and machine processing capabilities listed in Table 4. It should be noted that the term "target" is here used in a very general sense to mean the focus of interest in a given operational problem. It is inclusive of such objectives as terrain features, cartographic parameters, as well as hostile objects to be tracked and/or destroyed.

The prerequisite for automatic processing, of course, is the discovery of target characteristics which uniquely set it apart from its background and environment. Occasionally, a single target characteristic (such as IR radiance in missile guidance) can be used for automatic processing. Under adverse weather conditions, however, such a single characteristic may not uniquely distinguish a target from its environment, and it becomes necessary to find other, or alternate, characteristics if automatic processing is to be applied. Thusthe target and its environment determine the choice of identifying characteristics.

Table 3

Military Image Processing Tasks for Possible Automation

1 RECONNAISSANCE	Detection & classification of targets & other objects (terrain analysis, establishment of data bases, damage assessment).
2 CARTOGRAPHY	Topographic mapping, thematic mapping, topographic data base, point processing, map revision.
3 WEAPON GUIDANCE	Target tracking & following; guidance to fixed targets.
4 NAVIGATION	Air; ground; sea; space.
5 TECHNICAL INTELLIGANCE	Weapon system assessment; material evaluation.
6 METEOROLOGY	Prediction; real time use.
7 SECURITY	Area defense; personnel identification.
8 REMOTE CONTROL	Robot operations.

Table 4
State of the Art of Some Military (Semi) Automatic Image Processing Applications

ENVIRONMENT	TARGET	PRINCIPAL SENSOR	PURPOSE OF SENSING	STATE OF MACHINE PROCESSING ART
Air/Space	Aircraft; spacecraft; missiles	Radar IR	Tracking; attack	Advanced
Sea surface	Ships	Radar; camera; sonar; scanners	Detection; tracking; classification	Machine processing for tracking possible; requires operator intervention.
Sea subsurface	Submarines; mines; oceanography	Sonar; magnetic anomoly detection	Detection; tracking; classification; attack	APR methods applied to processing of sensor array data (sensor limited).
Terrain surface	Land vehicles; structures; weapon systems; cartographic & strategic applications	Camera; scanner; IR; radar	Detection; classification; terrain analysis	Preprocessing advanced. APR only applicable in certain limited cases. APR being applied to a limited extent in cartography (sensor limited).

Table 5 lists and defines the image processing techniques that RSG-4 believed needed to be perfected in order to be able to automate the military tasks listed in Tables 3 and 4. Table 6 presents a series of succinct statements about the state of the art of these image processing techniques, and also identifies by number the unsolved problems associated with each technique. The unsolved problems are listed and defined in Table 7. It should be noted that the list in Table 7 is not necessarily all inclusive; in particular there is little or no recognition of that class of problems that arises when several algorithms or procedures are linked together to solve a complex problem. These are basically "systems" problems, and there appear to be three critical areas where much work remains to be done:

a. Digital storage, computing capacity, and hardware architecture.

b. Audio-visual display requirements for semiautomatic interactive pattern recognition systems.

c. Adaptive and/or interactive processing techniques in general, and as design tools for optimizing automatic pattern recognition systems.

Table 5
Image Processing Techniques Requiring Perfection

1 MULTISPECTRAL ANALYSIS. Extraction of information concerning targets in imagery through the use of images made in many parts of the EM spectrum. Typically includes visible, IR, and RF portions of the spectrum.

2 MOTION DETECTION. Recognition of targets through their apparent motion with respect to the background.

3 CHANGE DETECTION. Detecting changes in a scene by subtracting a previous image from a current image of the scene. This highlights any changes in the scene (but one must be careful to ensure that the images are the same scale and orientation).

4 FEATURE EXTRACTION AND TEXTURE ANALYSIS. Feature (characteristic) extraction is the process of converting an image into a set of significant numbers and/or relations, so appropriate automatic data processing techniques can be applied.

5 IMAGE MATCHING. Performing processing such as rectification, rotation, scaling, etc., on different images of the same scene so they may be compared.

(continued)

(Table 5 continued)

6 SCREENING AND PRECONDITIONING. Preprocessing a picture for automatic analysis, and then automatically eliminating those images having no patterns of interest. Also, cueing an analyst as to where in an image a pattern may be found.

7 IMAGE DATA STORAGE, RETRIEVAL, AND MERGING. Storing and locating images so they may be found quickly and merged into reports; or two or more images may be combined into one for analysis.

It should be noted that the third and fourth questions listed in Section 2.4 are not included. It was decided that these questions (regarding costs, and implementation requirements) were very application-specific, and should more properly be answered as part of any cooperative research effort that might be developed. These two questions were also deleted from the remaining technology assessments.

The RSG-4 review of processing capability revealed yet another barrier to the development of improved PR capability: the necessity for processing enormous amounts of data by mostly serial methods. The development of a significant parallel processing capability would overcome many of the present difficulties; a number of architectures are being investigated including optical, parallel digital, associative, pipeline, and multiple processors.

Table 7
Glossary of Unsolved Problems in Image Processing

1 ENVIRONMENTAL INFLUENCES AND NEAR-TIME HISTORY. Effects of current and recent events that affect the response of an object or scene in any frequency band used to form the image.

2 TARGET CHARACTERISTICS. Shape, size, reflectance, emission spectra, color, texture, shadow, etc., enabling identification or detection of targets in a frame of imagery.

3 APPROPRIATE SENSOR RESOLUTION (ACTIVE AND PASSIVE SYSTEMS). Number of separable points contained in any image. May be limited by grain size of photographic film, and memory size of processing system.

4 PRECISE SUPERPOSITIONING OF IMAGERY.

5 COMBINATORIAL ALGORITHMS FOR MULTISPECTRAL DATA ANALYSIS.

(continued)

(Table 7 continued)

6 INTERACTION OF FREQUENCIES. Changes in the response of an object in one frequency band when hit by other frequencies. (Example: Kapton changes its optical reflectivity and color when bombarded with X-rays.)

7 REFERENCE CALIBRATIONS FOR SCANNERS.

8 SCENE NORMALIZATION AND CONTRAST CONTROL FOR SUCH INFLUENCES AS SUN ANGLE, ETC. Processing one or more images so they may be compared. This often includes rectification to normalize look angles, scaling to change altitude, and rotation/translation to correct for differences in orientation/direction of the sensor platform.

9 UNDERSTANDING OF FREQUENCY EFFECTS. Response of an object when illuminated by a given frequency.

10 DATA BASE ORGANIZATION.

11 COMMUNICATION BETWEEN RESEARCHER AND USE.

12 DETECTION OF MOTION AT HIGH AND LOW TARGET SPEEDS.

13 BRIDGING FOR NON-CORRELATION. In image superpositioning, a means for bridging non-correlated areas in automatic processing.

14 DISCRIMINATION BETWEEN BACKGROUND AND TARGET IN NON-DOPPLER MOTION DETECTION.

15 DETECTION OF NON-RADIAL MOTION.

16 CHANGE ANALYSIS AND INTERPRETATION.

17 OPTIMAL FEATURE SELECTION (HEURISTIC/STATISTICAL/ADAPTIVE).

18 NO FEATURE CATALOG EXISTS FOR VARIOUS TYPES OF TARGETS AND BACKGROUNDS.

19 FEATURE EXTRACTION TECHNIQUES ARE LARGELY UNDOCUMENTED.

20 FEATURE EXTRACTION AND CORRELATION.

21 SPEED AND CUEING. Rapidly selecting imagery of interest, and cueing operator to regions of interest.

22 FORMATING.

23 MAKING AND USING MICROGRAPHICS.

Table 6
State of the Art of Image Processing Techniques
(As of August 1974)

TECHNIQUE	PRESENT STATE OF THE ART[1]	UNSOLVED PROBLEMS[2]
1 Multispectral Analysis	B	1-11.
2 Motion Detection	A-for Doppler shift in imaged radar/sonar for middle rates of speed. C-for optical systems.	3, 12, 14, 15. 4-in other than Doppler shift methods.
3 Change Detection	A-C for special cases.	3, 4, 5, 8, 16. 10-for long-term changes.
4 Feature Extraction	B	17, 18, 19.
5 Image Matching	A-for cartography. B-C for reconnaissance.	1, 4, 8, 10, 13, 20.
6 Screening and Preconditioning	B	1-11, 21, 22.
7 Image Data Retrieval and Merging	B	1, 4, 8, 10, 11, 13, 20-23.

[1]Ratings: A=useful now; B=shows promise; C=a long way to go.

[2]See Table 7.

2.6 Technology assessment of speech recognition

The formal assessment of military applications of automatic speech processing and recognition was begun at the sixth RSG-4 meeting (May 1974). However, to obviate some of the difficulties encountered with the image processing assessment, a list of military tasks for possible automation in speech recognition was developed at the fifth meeting. This list is presented in Table 8.

At the sixth meeting, independent assessments were presented by Helmut Mangold (Germany), Louis Pols (Netherlands), Edwin Newman (U. K.), and E. P. Neuberg and D. C. Hodge (U. S.) [11]. A synthesized version [12] of the speech recognition assessment has recently been published in the open literature [13], so only a summary of the results of the assessment will be presented here.

Table 9 lists the speech processing techniques that have to be perfected in order to be able to automate some or all of the military tasks listed in Table 8. Table 10 indicates the state of the art of each technique on a three-point scale, and includes a list of the unsolved problems associated with each of the processing techniques. Table 11 presents a glossary of unsolved problems.

To date the greatest military applications of speech recognition, per se, have been achieved in the areas of speaker verification and voice data entry. Speaker verification is presently being used to control access to secure areas, often in conjunction with other identity verification techniques such as face recognition, signature verification, etc. In the speaker verification problem (as opposed to speaker recognition) the speaker is cooperative, his identity is known to the system, and his spoken data base is in the system's memory. The input communication channel can be a high-quality microphone, or noise-cancelling techniques can be used where necessary. The same communication channel can be used for both the reference and test sets of voice samples. Present techniques in speaker verification produce results on the order of one percent rejection of true speakers, and two percent acceptance of impostors, using only one reference utterance and 120 speakers. By using two reference utterances, the false acceptance rate can be reduced to less than 0.25 percent. Further refinements that are needed for military applications include operation over telephone-bandwidth

Table 8
Military Speech Processing Tasks for Possible Automation

1 SECURITY	Speaker verification (authentication); speaker identification (recognition); determining emotional state of speaker (e.g., stress); recognition of spoken codes; secure access voice identification, whether or not in combination with fingerprints, facial information, identity card, signature, etc.; surveillance of communication channels.
2 COMMAND AND CONTROL	System control (ships, aircraft, fire control, situation displays, etc.); voice-operated computer input/output (each telephone a terminal), data handling and record control; material handling (mail, baggage, publications, industrial applications); remote control (dangerous material); administrative record control.
3 DATA TRANSMISSION AND COMMUNICATION	Speech synthesis; vocoder systems; bandwidth reduction or, more general, bit-rate reduction; ciphering/coding/scrambling.
4 PROCESSING DISTROTED SPEECH	Diver speech; astronaut communication; underwater telephone; oxygen mask speech; high "G" force speech.

Table 9
Speech Processing Techniques Requiring Perfection

1 SIGNAL CONDITIONING. Some processing of speech signals may be necessary to compensate for different characteristics of input channels, such as overall signal level and differential delay. Also, it may be possible to preprocess to improve speech quality, or S/N ratio, or to remove long silences.

2 DIGITAL SIGNAL TRANSFORMATION. The digitized speech signal is transformed in preparation for the extraction of parameters. Processes used include Fourier and Walsh transforms, correlation, linear predictive coding and digital filtering.

3 ANALOG SIGNAL TRANSFORMATION AND FEATURE EXTRACTION. The signal can be transformed by hardware, such as filter banks and correlation devices. Transforms can be digitized for further processing, or parameters and features can be extracted in a continuous manner for presentation to decision networks or algorithms.

4 DIGITAL PARAMETER AND FEATURE EXTRACTION. Calculations are done on the transformed signal to extract relevant parameters, such as formant tracking, pitch extraction and principle components analysis.

5A RESYNTHESIS. Speech parameters extracted, as mentioned above, in speech compression systems or stored in voice playback systems, may be transformed into acceptable acoustic speech signals.

5B ORTHOGRAPHIC SYNTHESIS. In the translation of written materials to speech, a number of techniques must be developed. Some of these techniques are similar to those cited in the paragraphs above. One of the most important is the development of speech morphology.

6 SPEAKER NORMALIZATION, SPEAKER ADAPTATION, SITUATION ADAPTATION. The effectiveness of parameters in carrying relevant speech information depends on characteristics of individual speakers and on operational situations. This could mean that systems must be trained or must adapt to optimize parameters.

7 TIME NORMALIZATION. In recognition of isolated utterances, normalization is imposed to compensate for local and global differences in speech rate. Both linear and nonlinear schemes can be used.

(continued)

(Table 9 continued)

8 SEGMENTATION AND LABELING. Segment boundaries are set, e.g., at points of rapid change, formant positions, voicing, spectral shape or other parameters. Segments may be labeled probabalistically to acoustic-phonetic classes. Prestored knowledge of features and parameters for the various classes of segments are used in the decision.

9A LANGUAGE STATISTICS. Language statistics and partial recognition are used to predict and evaluate words at specific points in an utterance.

9B SYNTAX. The grammar of the task is used to predict and evaluate word categories at specific points in an utterance.

9C SEMANTICS. Knowledge of the task domain is used to predict and evaluate subject matter at specific points in an utterance.

9D SPEAKER AND SITUATION PRAGMATICS. In determining the semantics of speech, certain aspects of the utterances are related to an underlaying assumption about what the speaker would generally consider an appropriate response. The development of this type of knowledge is required for speech understanding systems. Knowledge of the situation that gave rise to the utterances is also required for reliable interpretation and execution of the task to be performed in response to the utterance.

10 LEXICAL MATCHING. Strings of linguistic-phonetic elements hypothesized by the linguistic part of the system are compared with strings of acoustic-phonetic elements derived from an utterance. A quantitative goodness of match is calculated.

11 SPEECH UNDERSTANDING. All sources of knowledge (acoustic, phonetic, pragmatic, semantic, syntactic) are used in combination to reconstruct the utterance and/or determine its meaning.

12 SPEAKER RECOGNITION. Speaker-specific parameters are extracted and compared with stored parameter sets from known speakers.

13 SYSTEM ORGANIZATION AND REALIZATION. Systems must be developed keeping in mind use by humans and cost-effectiveness factors.

14 PERFORMANCE EVALUATION. Present development of all speech systems requires the determination of the quantitative value of each possible technique studied. Only by the use of stored speech samples is this performance evaluation possible.

Table 10
State of the Art of Speech Processing Techniques

PROCESSING TECHNIQUE	STATE OF THE ART[1]	UNSOLVED PROBLEMS[2]
1 Signal Conditioning	A, except speech enhancement (C)	1,15,20,23
2 Digital Signal Transformation	A	1,15,20
3 Analog Signal Transformation & Feature Extraction	A, except feature extraction (C)	1,2,6,14-16,20,24,25
4 Digital Parameter & Feature Extraction	B	1,2,6,14,16,20,24,25
5A Resynthesis	A	4,7,20,25
5B Orthographic Synthesis	C	4,6-8,19,26-28,29
6 Speaker Normalization & Adaptation; Situation Adaptation	C	15-17,19,20,23-25,29
7 Time Normalization	B	3,16,20,25,29
8 Segmentation & Labeling	B	1,4-9,11,13,16 18-20,24,25
9A Language Statistics	C	5,8,9,11,12,14,20,24,25
9B Syntax	B	6,7,9,12,14,20,25
9C Semantics	C	6,7,9,10,12,14,20,25
9D Speaker & Situation Pragmatics	C	3,6,12,14,16,18,19,23
10 Lexical Matching	C	7-9,12-14,20,25

(continued)

[1]Ratings: A=useful now; B=shows promise; C=a long way to go.

[2]See Table 11.

(Table 10 continued)

PROCESSING TECHNIQUE	STATE OF THE ART[1]	UNSOLVED PROBLEMS[2]
11 Speech Understanding	B-C	5,9,12,14,16,18, 20,23,25
12 Speaker Recognition	A for speaker verification; C for all others	14,16,17,19,20,24, 25
13 System Organization & Realization	A-C	21,22
14 Performance Evaluation	C	1,6-11,18-20,24-28

[1]Ratings: A=useful now; B=shows promise; C=a long way to go.

[2]See Table 11.

channels, and over radio links which involve peculiar S/N and level fluctuation problems, plus developing techniques that will permit context-free speaker verification.

Voice data entry is the other military application area in which speech recognition, per se, is presently being applied. Voice data entry is being used in a variety of hands-busy situations as well as to reduce data transmission errors by eliminating hand transcription (as for computer entry). Present voice data entry systems are based on isolated word recognition techniques, and these types of systems generally involve the following limitations: (i) vocabulary limited to about 75 words; (ii) no speaker normalization is used; (iii) every speaker must train the system on every word in the vocabulary; and (iv) the words must be spoken in a discrete manner.

Further developments in voice data entry in the immediate future are likely to be in two directions. One will be improving systems so they will be speaker-independent, but have other current limitations remain the same. The other direction is to eliminate the requirement for discrete word input by developing techniques that will allow short phrase recognition and connected word or connected digit recognition.

If we broaden this topic to include speech processing as well as recognition (which, of course, was done in the technology

Table 11
Glossary of Unsolved Problems in Speech Processing

1	Detect speech in noise; speech/nonspeech.
2	Extract relevant acoustic parameters.
3	Dynamic programming (nonlinear time normalization).
4	Detect smaller units in continuous speech.
5	Establish anchor point; scan utterance left to right.
6	Stressed/unstressed.
7	Phonological rules.
8	Missing or extra added ("uh") speech sounds.
9	Limited vocabulary; possibliity of adding new words.
10	Semantics of (limited) tasks.
11	Limits of acoustic information only.
12	Combine acoustic, syntax and semantic information.
13	Recognition algorithms.
14	Hypothesize and test; backtrack; feed forward.
15	Effect of distortions (physiological, physical, mechanical).
16	Adaptive and interactive quick learning.
17	Mimicking; uncooperative speaker(s).
18	Necessity of visual feedback, error control, rejection level.
19	Consistency of references.
20	Real-time processing.
21	Human factors engineering problems.
22	Cost effectiveness.
23	Detect speech in presence of competing speech.

(continued)

(Table 11 continued)

24	Economical ways of adding new speakers to system.
25	Use of prosodic information.
26	Coarticulation rules.
27	Morphology rules.
28	Syntax rules.
29	Vocal tract modeling.

assessment--see Table 8) then other current military applications include channel vocoders and helium speech unscramblers.

Despite the large amount of money which has recently been devoted (particularly in the U. S.) to research and development in the area of continuous speech understanding, there is no stated military requirement for such a capability at present. On the other hand, once the next generation of such systems comes along, and some of the present limitations have been overcome [14], we will probably begin to see some of this developing technology applied to military problems.

In addition to the specific applications mentioned above, the following are additional examples of military problems to which speech recognition and processing technology is presently being applied:

a. Digital narrowband communication system: A massive effort is underway to develop and implement an all-digital communication system.

b. Training systems: A limited speech understanding system is under study for use in a military training system.

c. On-line cartographic processing system: Studies are underway to use speech recognition and voice response techniques with cartographic point and trace processing systems.

d. Word recognition for militarized tactical data systems : Word recognition, speaker verification, and voice response will be used for message entry to a tactical data system.

e. Voice recognition and synthesis for aircraft cockpit: Existing word recognition systems are being tested under simulated cockpit environments.

2.7 Technology assessment of mechanical wave processing

The first discussion of the application of APR techniques to acoustic, seismic, and sonar signals took place at the fifth RSG-4 meeting (November 1973). (For convenience, this topic was referred to as "sound/seismic/sonar.") Surveys of national MOD interests in an assessment and/or cooperative research were discussed at the next two meetings; in general, the consensus was that the results of a technology assessment would be very useful, but there was considerable doubt about cooperative research due to the sensitivity of all the data.

Largely to avoid the continued reference to "sonar", the name of this topic was changed at the seventh meeting. All of the signals of interest represent mechanical waves traveling in various media, so it was decided to re-title this topic "Automatic Processing of Mechanical Waves in Solids, Liquids, and Gases, for Military Purposes Such As Acoustic, Seismic, and Sonar Target Detection and Classification". Also at the seventh meeting a list of possible military problems and applications was developed to guide further discussion; that list is shown in Table 12.

Table 12
Possible Military Problems and Applications in the Automatic Processing of Mechanical Waves in Solids, Liquids and Gases*

1 SURVEILLANCE (PASSIVE AND ACTIVE)	Detection and classification of military vehicles (air/land); fixed objects (mines); explosions/implosions (type/location); underwater and surface vehicles; personnel.
2 NAVIGATION	Position checking; confined and hazardous sea areas; underwater mapping.
3 COMMUNICATION	Underwater communications (underwater telephone); IFF.
4 INTERCEPT	Detection and classification of hostile transmissions.
5 DAMAGE DETECTION	Anticipating equipment failures (engines; gun tubes); quality control (nondestructive testing).
6 SIMULATORS	Realistic signals for operator and command training systems.

*Revised from Annex E to Ref. 15.

At the eighth meeting (July 1975) RSG-4 constituted an Ad Hoc Group on Mechanical Waves, composed of the national specialists present at the meeting. This group was charged with the responsibility of deciding how to structure a technology assessment, and with actually carrying out the assessment. COL Russell B. Ives of the U. S. was appointed Chairman of this group, a position that he held until the conclusion and publication of the assessment.

COL Ives presented a proposed outline for the mechanical waves assessment for discussion at the eighth meeting -- see Table 13. This "straw man" was used to stimulate discussions of the state of the art, directions of current national research programs, and potential areas for future cooperation. At that time the greatest interest was shown in passive sonar, with active a close second; however it was recognized that any exchange of passive sonar signatures would be impossible, and active sonar data exchange would be difficult. It was agreed, however, that an attempt would be made between the eigth and ninth RSG-4 meetings to draft a technology assessment of the topic for discussion at the ninth meeting.

At the ninth meeting the proposed outline (Table 13) was found to be unworkable by some of the specialists. As a result the technology assessment was formulated as shown in Tables 14 and 15.

Table 14 lists the main applications of military interest. These have been divided into three areas: passive listening systems, active echo analysis systems, and communication systems. Against each of these major headings, various systems operating in the three different media are considered. For each particular system, the type of sensor platform used is listed together with the targets or objects which provide the focus of interest. In addition, the purpose of the system in terms of its ability to detect, classify, localize, track, etc., is identified.

(Keep in mind that some systems exist which use active nonmechanical waves to detect and analyze mechanical waves, e.g., EM, radar, and lasers. These systems are not considered to be active mechanical wave systems and are, therefore, excluded.)

The brief statements made in Table 14 concerning the state of the art against the various applications are included to indicate the degree to which operational systems, and those in advanced stages of development, make use of APR techniques. Although certain fully automatic systems are identified (e.g., homing torpedoes, and mine detection systems), these are almost invariably based on operating concepts which are too simple to be properly considered as APR techniques.

Table 13

Proposed Outline for a Technology Assessment of the Automatic Processing of Mechanical Waves in Solids, Liquids, and Gases

I. Current Military Requirements
  A. Successful Applications
    1. Development time
    2. Useful life span
    3. Anticipated obsolescence
  B. Unsuccessful Applications
    1. Development time
    2. Deficiencies noted
    3. Proposed vs. actual performance
    4. Identified corrective research

II. Future Military Requirements
  A. Identified Applications
  B. Projected Technological Deficiencies
    1. Requisite basic research (6.1)
    2. New engineering techniques (6.2)
    3. Essential advances in technology (6.3+)
  C. Anticipated Resource Allocations
    1. Time
    2. Cost
    3. Manpower

III. Technical Tools
  A. Signal Conditioning Techniques
    1. Active and passive filters
    2. Compression and expansion methods
    3. Multiple channel superposition
  B. Feature Extraction
    1. Physical features
    2. Structured features
    3. Mathematical features
    4. Transform domains
      a. Fourier
      b. Hadamard
      c. Binary
  C. Clustering algorithms
    1. Statistical
      a. Means
      b. Covariance
    2. Clustering
      a. Isodata
      b. Hierarchical

(continued)

(Table 13 continued)

III. Technical Tools
- C. Clustering Algorithms
  - 3. Distance measures
    - a. Geometric
    - b. Mahalanobis
    - c. Bhattacharya
  - 4. Mappings
    - a. Linear (Karhunen-Loeve)
    - b. Nonlinear
      - (1) Sammon
      - (2) Fukunaga-Olsen
  - 5. Decision functions
    - a. Bayes linear and quadratic
    - b. Piecewise linear
    - c. Fisher discriminants
    - d. Language strings
- D. Hardware
  - 1. Transducers
  - 2. Data channels
  - 3. Remote vs. central processing
  - 4. Processors
    - a. Minicomputers (single and clustered)
    - b. Large scale processors
    - c. Peripherals
  - 5. Displays
    - a. Environmental restrictions
    - b. Media
    - c. Complexity required

IV. International Areas of Cooperation
- A. Areas Which Would Benefit
  - 1. Time
  - 2. Cost
  - 3. Accuracy
  - 4. Reliability
- B. Areas Which Preclude Cooperation
  - 1. Sensitive due to expressed interest
  - 2. Sensitive due to data or sources of data
  - 3. Lack of interest

V. Recommendations
- A. Resource Allocations Within NATO
- B. Realistic End Products Within Specified Time Frame
- C. Areas of Responsibility
- D. Reporting Procedures and Dissemination of Results

Table 14
Military Applications of Mechanical Waves and State of the Art

METHOD	MEDIUM	TARGETS	PURPOSE	SENSOR CARRIER	STATE OF THE ART
			A. Passive Listening Systems		
Sonar	Water, water-air	Ships, submarines, aircraft, decoys, personnel, torpedoes, explosions, implosions	Detection, classification, localization, tracking	Bottom arrays, towed arrays, helicopters, surface ships, submarines, sonobuoys, torpedoes, mines	Limited automatic tracking. Most tasks require operator intervention.
Doppler Analysis	Water air	Submarines, ships, torpedoes, aircraft, decoys	Classification, tracking, localization	(same as above)	(same as above)
Intercept	Water	Active range measurement, communication systems	Detection, classification, localization, tracking	Submarines, torpedoes, ships, fixed installations, mines	No existing systems using APR techniques are known.
Airborne Sound	Air	Detonations, aircraft, personnel, vehicles, stationary engines	(same as above)		Some elementary APR systems exist. Greater success has been achieved with detonations.

(continued)

(Table 14 continued)

METHOD	MEDIUM	TARGETS	PURPOSE	SENSOR CARRIER	STATE OF THE ART
Vibration Analysis	Mechanical structures, air	Vehicles, stationary engines	Detection, classification, failure prediction, quality control	N/A	Fully automatic systems are not sufficiently reliable.
Seismic	Earth (surface & body waves)	Personnel aircraft, vehicles, fixed	Detection, classification, localization, tracking	Surface of earth	Some APR techniques exist for a limited number of single targets.
Sea Surface Waves (hydrostatic pressure)	Water	Ships, submarines, decoys	Detection, classification	N/A	Some automatic detection systems exist.

(continued)

(Table 14 continued)

METHOD	MEDIUM	TARGETS	PURPOSE	SENSOR CARRIER	STATE OF THE ART
			B. Active Echo Analysis Systems		
Echo Sonar	Water	Surface ships, submarines, mines, torpedoes, wrecks, sea bottom	Detection, classification, localization, tracking	Surface ships, submarines, helicopters, buoys, torpedoes, divers	Some semiautomatic methods giving limited detection, tracking, & classification have been developed.
Echo Sounding	Water	Bottom	Depth measurement, reflection coefficients, profiling	Surface ships, submarines	No existing systems using APR techniques are known.
Doppler Analysis	1) Water	Bottom	Navigation	Surface ships, submarines	Some systems using elementary APR techniques have appeared.
	2) Air	Personnel, waves, vehicles	Detection, classification, localization, tracking	Fixed installations	(same as above)

(continued)

(Table 14 continued)

METHOD	MEDIUM	TARGETS	PURPOSE	SENSOR CARRIER	STATE OF THE ART
Echo Seismic	1) Earth	Profiles, discontinuities	Resource exploration, tunnel location	Surface of the earth	Some APR systems exist for ranges to 100 M.
	2) Water	Submarines; bottom	Resource and profile exploration	Surface of the earth	No known APR systems exist.
Structure Analysis	Mechanical structures	Material discontinuities	Nondestructive testing	N/A	Some elementary APR systems beginning to appear.
			C. Communication Systems		
Data Transmission	Water	Surface ships, submarines, buoys	Reliable machine to machine communication; IFF	Surface ships, submarines, buoys, fixed installations	No known APR systems. Some sophisticated error correcting codes developed.
Speech Transmission	1) Water	Ships, divers, submarines	Person to person communication	Ships, submarines, divers, fixed installations	See Ref. 13.
	2) Artificial Atmospheres	Personnel	(same)	Underwater chambers	See Ref. 13.

Table 15
Unsolved Problems in Mechanical Wave Processing

1 ENVIRONMENTAL EFFECTS. Imperfect understanding of the physics of the medium and its boundaries gives rise to uncertainty in the time and frequency response observed from both the target of interest and other sources (i.e., nonstationary and multipath effects).

2 TARGET CHARACTERISTICS. Complex target structure causes uncertainties in their reflection and/or emission characteristics. This problem is compounded when multiple targets are observed.

3 BACKGROUND CHARACTERISTICS. Insufficient knowledge about noise generating and back scattering mechanisms in the propagation media make prediction of the performance of processing systems difficult.

4 SENSOR RESOLUTION. The choice of resolution affects the performance of processing systems. An optimum choice is complicated by distorting effects of the medium and uncertainties about target and background characteristics. In many practical cases, sensor size, resolving power, and time constraints may be limited by considerations relating to the platform on which it is to be mounted as well as the physical characteristics of the sensor itself.

5 OPTIMAL FEATURE SELECTION. A variety of theoretical and empirical techniques have been developed for the generation and selection of feature sets to describe patterns. Little is known about techniques for optimizing the generation of feature sets and feature generation is highly data dependent.

6 COMBINATORIAL ALGORITHMS. The best methods for combining features, or reducing the feature set, to obtain maximum discrimination between pattern classes have not been formulated.

7 NORMALIZATION. Conflicting requirements of both targets and background give rise to compromise in the choice of a strategy for normalizing data.

8 MOTION DETECTION BY NON-DOPPLER MEANS. The detection of nonradial motion and radial motion is complicated by problems associated with sensor resolution and the difficulty of correctly associating background and target data.

(continued)

(Table 15 continued)

9	DOPPLER DETECTION. Although a well established technique, problems still exist in discriminating slow speed radial targets from a background.
10	DATA BASES. Frequency methods and results are based on a statistically insignificant number of samples collected in a variety of uncontrolled conditions. This gives rise to uncertainty as to how representative are the results obtained as well as the performance which might be observed in other conditions. Additional work is needed to optimize the size of a data base. Specifically, to ascertain under what conditions a representative target would be added to a data base or replace an existing entry within the data base.
11	PRECONDITIONING. Like feature generation and selection, a variety of techniques have been studied. Little, however, is known about optimum methods to preprocess data in order to reduce processor loading without undue loss of performance.
12	FEATURE TRACKING. Features may not be time invariant. Superior algorithms must be developed to cope with rapidly changing features and widely varying S/N ratios.
13	DATA PROCESSING. Due to the fact that large time-bandwidth product signals are to be processed, there is a need for high capacity, on-line processors.
14	CLASSIFICATION LOGIC RESTRUCTURING. For each incorrect classification, a technique is required to identify the responsible features and associated decision function. Some interactive process would be desireable to permit an immediate upgrading of the classification logic.

The problems associated with the successful applications of fully automatic and semi-automatic pattern recognition techniques to the majority of the systems mentioned are considered to be too numerous and varied to permit a comprehensive enumeration. An attempt has been made, however, to cite the major problem areas which require a fuller understanding. Research in these areas should provide the information necessary to make more extensive applications of these APR techniques possible.

The requisite research must provide a better understanding of all of the parameters which characterize the desired target, and the identification of those features which uniquely separate the target from the other distracting data. More insight must also

be gained with respect to the complex effects of the dynamic, non-homogeneous propagation media in which the target and sensor platform are usually immersed. This is reflected in the first three problem areas identified in Table 15. Sensor resolution has been mentioned as a problem, because it has a significant effect on the received data. It should be noted that this point was of no direct concern to RSG-4, since development of sensors is the responsibility of other NATO groups (see Table 2). Also, in the majority of cases, the interests of the participating nations was in applying APR techniques to existing sensor systems.

The mechanical wave assessment [16] concluded by noting that until a much better understanding of the various problem areas has been reached, a great deal of system design will continue to rely heavily on the experience and intuition of the individual designer. Also, progress by individual designers may be limited by the quality and quantity of suitable data bases as well as insufficient funds to explore a meaningful variety of analytical techniques. These difficulties, among others, could probably be largely overcome through the adoption of unified approaches by the RSG-4 countries including structured cooperative research programs.

2.8 Proposed cooperation on image processing

The first draft of the image processing technology assessment [8] was developed at the November 1973 meeting of RSG-4 (see Section 2.5, esp. Tables 4 - 8). Thereafter this draft was circulated to defense researchers in the participating countries for comment, and for expression of interest in cooperative research on the various unperfected techniques and unsolved problems. The survey results were first discussed at the May 1974 meeting of RSG-4, but no conclusions were reached. However, it became clear that we would have a better chance of obtaining substantive comments if we had a "strawman" proposal to circulate for comment.

The first complete proposal for cooperation was developed at the August 1974 meeting [Annex G to Ref. 15]. This proposal was based on a recognition of the fact that in order to obtain national support of specific projects it would first be necessary to demonstrate RSG-4's ability to undertake cooperation. This situation (which may be obvious to some readers) derives from a number of considerations, including the following:

a. All of the participating nations had on-going research programs planned for two or more years in advance, and would be unlikely to change those plans.

b. Funding levels are likewise programmed for two or more years in advance; therefore, no major sources of funding are immediately available.

c. Parallel approaches to common image processing problems are being pursued in the various countries; the managers of such programs would be unlikely to abandon the hardware systems involved, nor the researchers the theoretical models nor priorities involved.

RSG-4 thus concluded that the immediate goal of a cooperative research plan should have the following properties [15] :

a. It should recognize that ongoing research in the participating countries cannot be changed (at all) without allowing a period of one to two years of adjustment.

b. It should be based on current efforts and exploit current capabilities to the extent possible.

c. Initially, it should involve the minimum amount of additional effort on the part of the national scientists.

d. It should be based on common problems, i.e., problems common to every laboratory in every country.

e. Above all, it should be possible of achievement in a realistic time frame; and it should be a phased plan so some useful capabilities emerge relatively quickly.

After reaching these conclusions an ad hoc working group (headed by Warren E. Grabau, U. S. Army Engineer Waterways Experiment Station) spent a weekend writing the first plan for cooperation on image processing. This plan consisted of five phases:

a. Phase 1: Development of software that would make it possible to freely transmit data bases among laboratories in the participating countries.

b. Phase 2: Adapt existing computer software available in the various laboratories to the hardware of such other laboratories as need the capability.

c. Phase 3: Formulate critical military image processing requirements; document national priorities.

d. Phase 4: Prepare engineering specifications for parallel processing hardware and related software.

e. Phase 5: Conduct research on location and identification of tactical targets in complex scenes.

Phase 1 of this plan was derived from the fact that, at that time, it was commonly impossible or impractical for image processing laboratories to exchange data bases. (But, obviously, utilization of common data bases would be an essential part of any international cooperative program that might result in standardized military procedures.) For a variety of technical and administrative reasons each laboratory has developed its own unique format for storing its digitized image data base. Even if we ignore the 7- vs. 9-track tape incompatibility, there were (and probably are) both hardware and software differences that make data base exchange difficult or impossible. The problem had reached such ridiculous dimensions that we found, for example, that two research groups in the same building at a U. S. defense installation could not exchange data bases!

Not only had each laboratory developed its own storage format for digitized images, but each such format tended to perpetuate itself. Thus it was not appropriate to try to define a "standard" data format to which all participating laboratories could convert their data. Instead, what was proposed was the specification and standardization (among the participating laboratories) of a <u>transfer format</u> into which data bases could be transformed, and from which each laboratory could transform data in its own storage format. In other words, to utilize such a transfer format, each participating laboratory would have to write only two new programs: one to transform its data into the transfer format, and another to transform data out of the transfer format.

Apparently, there had been one or more earlier efforts in the image processing community to accomplish this same thing. I can recall discussion of this topic at a symposium organized by the EIA Committee on Imagery Pattern Recognition [17]. However, that effort had gotten hung up on "standardization" in the NBS or IEC sense, whereas RSG-4 was proposing standardization in the sense of agreement among specific parties who want to do something collectively.

The steps involved in accomplishing the goal of developing a transfer format were envisioned by RSG-4 as consisting of the following:

a. Determine the precise data storage formats currently used by the participating laboratories.

b. Formulate transfer formats. It was assumed that two such formats would be required, one for 7-track (556 BPI) and one for 9-track (800 BPI) hardware.

c. Disseminate formats to labs, who would attempt to write the necessary transfer programs.

d. Evaluate all proposals for modifications to the transfer format(s) that arise from difficulties encountered in the trials.

e. Finalize formats, and run systems checks consisting of trial data exchanges among the participating labs. Prepare report describing the procedure and software.

Phase 2 of the proposed cooperative research plan, dealing with documentation and exchange of existing algorithms, was based on the common problem that many (if not most) image processing algorithms are not sufficiently documented. Each image processing laboratory usually has developed its own collection of algorithms (sometimes referred to as a "bag of tricks") such that each lab can do about the same kinds of processing of image data. For example, most laboratories have developed one or more algorithms for separating an image into fields on the basis of density classes. However, close examination often reveals that each laboratory has a unique procedure for achieving the desired product. As a result of the inadequate documentation of what an algorithm does, as well as <u>how</u> it does it, laboratories find it difficult, if not downright dangerous, to expand image processing capabilities by using borrowed algorithms. This problem has also been the subject of some investigation by other bodies [18].

As originally envisioned by RSG-4 this phase of the cooperative program involved the following steps:

a. Each laboratory prepares a list of its available algorithms, and decides which ones to develop documentation for.

b. A subcommittee collects the documented algorithms, and reviews them for needed amplification.

c. Laboratories revise the documentation as required.

d. The subcommittee collects the final versions, and organizes them for dissemination.

Phases 3 - 5 were not drafted in detail at the outset; it was assumed that these phases might change (they did) and that they could better be drafted in detail by the national image processing specialists who were to be appointed by the participants to conduct the cooperative programs.

The draft proposals were circulated to national researchers for comment, and Panel III was requested to approve establishment of a subgroup under RSG-4 to conduct the program. The remainder of the activities in image processing cooperation is covered in section 3.

2.9 Proposed cooperation on speech processing

The technology assessment of military applications of automatic speech recognition was initiated at the sixth RSG-4 meeting in May 1974 [11]; after it had been circulated to national speech researchers for comment it was published as a NATO report [12] in April 1976.

When the list of techniques to be perfected, and the list of unsolved problems in speech processing, were circulated for comment and for expressions of interest in cooperation, the initial returns were disappointing. At the August 1974 meeting only two countries were interested in cooperating on speech recognition, per se; by broadening the topic to speech processing, a total of three expressed interest. At that point it was decided to shelve the topic of cooperation and put our energy primarily into writing the combined NATO report [12].

At the July 1975 (8th) RSG-4 meeting there was further discussion of cooperation on speech processing, which may be summarized as follows:

a. There is already a great deal of international cooperation on speech processing, via national technical societies and regular international conferences. This cooperation includes countries outside NATO (e.g., Japan and USSR) where there is much interest in the topic. As a result, little interest has been expressed in RSG-4 for cooperation on unclassified problems.

b. National language differences cause processing problems, i.e., processing techniques that work with one language may not work with another. There are, however, a number of problems in common, such as speaker normalization, that might form the basis for cooperation.

c. The availability of the speech technology assessment report [12], with its emphasis on current and near term military applications, may stimulate interest in cooperation, particularly on classified problems.

Thus it was decided to continue internal discussions of possible topics for cooperation, and to continue dialogue with national researchers about their interests in cooperation.

At the 9th meeting (February 1976) four countries expressed some degree of interest in speech processing topics. As a result of this increase in interest, a very general proposal was developed for circulation among speech researchers in the participating countries [19]. This proposal consisted of a brief discussion of three

speech topics to be further explored for degree of interest: (i) speech feature extraction in vocoder systems; (ii) automatic speaker verification; and (iii) voice control (limited vocabulary--100 words; many speakers). The survey results reported to the 10th meeting (November 1976) [20] indicated that four countries were interested in cooperating on vocoders, three on speaker verification, and four on voice control. For three of these respondents, voice control represented their area of greatest interest. These data were taken by RSG-4 as a clear indication of sufficient interest to warrant preparation of more detailed proposals for cooperation.

The speech processing specialists who were present at the 10th RSG-4 meeting proceeded to discuss the prospects for cooperation, and to draft a Terms of Reference and a research plan for a subgroup on speech processing. The main thrust of this research plan was in the area of limited vocabulary voice input systems. This topic is one in which all the potential participants could conceptualize military tasks to which such systems would be applicable; this fact also meant that each country could list some (possibly unique) requirements that voice input systems would have to meet. For example, one application of considerable interest is voice input in aircraft cockpits. Such an application requires that the speech recognition system be able to overcome problems such as high ambient noise, mask breathing, high "G" forces, etc. Another country was interested in using voice input over a radio link in tactical situations; this use implies insensitivity to atmospheric interference and varying signal levels, as commonly encountered in radio communications.

The implementation plan that was proposed was to consist of several tasks (phases), but only the first one was developed in any detail at the 10th meeting. Task 1 was at that point envisioned as consisting of the following elements:

a. Developing a list of the possible military applications of voice input, i.e., as related to specific national interests.

b. Itemizing the specific scientific problems associated with each of the applications. Then listing national interests and existing research programs aimed at the various problems.

c. Discuss, and reach consensus, on the specific cooperative projects to be undertaken.

The draft Terms of Reference and research plan [Annex G to Ref. 20] were submitted to AC/243 Panel III with a recommendation that a subgroup on speech processing be established. The remainder of the cooperative activities on this topic are covered in Section 4.

2.10 Proposed cooperation on mechanical waves

Simultaneous with the preparation of the mechanical waves technology assessment [Annex G to Ref. 19], a list of possible areas of cooperation was developed, including: (i) general purpose algorithms, theory, and computer programs for APR; (ii) vibration analysis with respect to fault detection, quality control, and nondestructive testing; (iii) mathematical models of propagation; (iv) detection and classification of explosions by seismic waves; (v) theory and algorithms governing the use of multi-microprocessors in a single environment; and (vi) seismic and acoustic detection and classification of military vehicles and personnel (this would have included the development and exchange of data bases).

At the 10th meeting the Ad Hoc Group on Mechanical Waves concluded that there were four military applications areas in which there was interest in cooperation on processing techniques: (i) active sonar; (ii) passive sonar; (iii) bettlefield surveillance; and (iv) fault detection and maintenance in structures. Three research tasks were agreed on, viz.: (i) pooling of data bases; (ii) feature generation, reduction, and selection techniques; and (iii) classification methods. Each of these research tasks was viewed as intersecting with each of the four military applications areas [Annex I to Ref. 20]. A Terms of Reference was drafted, but completion of the research plan was deferred to the 11th meeting.

At the 11th meeting the Ad Hoc Group drafted a research plan encompassing all four of the military applications areas listed above. A set of nine phases were identified which applied to each of the applications areas:

a. Establish a standard data base format to facilitate an international exchange of data.

b. Exchange the data bases and insure that they are valid on the target computer.

c. Identify specific personnel to serve on the projects of interest.

d. Identify, develop, and exchange applicable APR algorithms.

e. Propose and examine any systems engineering required to implement the APR algorithms in a useful fashion.

f. Compile a comprehensive catalog of all of the APR algorithms, identify the purpose for which they were created, and cite any special considerations for their use.

g. Submit the algorithms to a variety of tests and record the testing environment and results.

h. Conduct a careful evaluation of the information collected above.

i. Prepare a final report.

This proposal [Annex F to Ref. 21] was submitted to Panel III for approval, along with a recommendation that a subgroup on mechanical waves be established under RSG-4 to conduct the cooperative research. However, at its subsequent meeting, Panel III rejected the Terms of Reference and research plan as being too general; instead, Panel III requested that a TOR be prepared for a subgroup on APR applied to battlefield surveillance. Also, RSG-4 was asked to prepare a statement as to the feasibility of cooperation on the sonar signal processing aspects of mechanical waves.

2.11 Proposed cooperation on APR in battlefield surveillance

RSG-4 participants having ongoing interests in the acoustic and seismic aspects of APR in battlefield surveillance sent specialists to the 12th RSG-4 meeting. A TOR and research plan were prepared as requested by Panel III.

In battlefield surveillance the objective is to detect, locate, and identify enemy forces on the battlefield by remotely-emplaced passive devices which sense mechanical waves. The problem is complex. The potential targets (men and machines) generate widely varying acoustic and/or seismic signals, depending on type of activity, rate of speed, conditions of the ground, meteorological conditions, etc. The media (earth, water, and air) through which mechanical waves propagate are far from being uniform, and thus the wave trains may be significantly distorted within relatively short distances. Battlefields are notoriously noisy, both acoustically and seismically, and this may add greatly to the problem of identifying the signal generated by a specific target or category of targets.

There are several major impediments to the development of greatly improved sensor systems, including the following:

a. The design data bases are inadequate. A design data base is a library of records of the signals generated by known targets (chiefly men, ground-contact vehicles, and low-flying aircraft) operating under carefully documented environmental conditions. The existing design data bases are inadequate in that: (i) too few target types are represented; (ii) records do not include an adequate sample of environments; and (iii) the site characteristics of many records may be inadequate.

b. The available algorithms for detecting target signals and classifying them according to position and target type have not been adequately validated.

Thus, the cooperative research proposal drafted at the 12th RSG-4 meeting [Annex A to Ref. 22] was aimed at mitigating these impediments to improved sensor systems. In brief, the proposed program involves combining design data bases, and transmitting and testing classification algorithms.

The proposed cooperative program on APR applied to battlefield surveillance consists of three primary tasks, each of which is briefly described below:

a. Task 1: Development of data transfer format. The objective of this task is to develop and disseminate to the participating nations a standardized format for recording mechanical wave data, plus all necessary ancillary data, in digital form on magnetic tape. This step is required to overcome the problems resulting from unique laboratory and national data formats. A standard data transfer format would largely solve this problem. It is planned to follow the transfer format developed by the image processing subgroup to the extent possible.

b. Task 2: Development of an algorithm transfer format. Such a format would make it possible for all interested laboratories to use all relevant computer programs available within the participating nations with a minimum of cost and time delay; it is also essential to the conduct of Task 3, below. It is planned to follow the existing algorithm transfer format developed by the image processing subgroup to the extent possible.

c. Task 3: Development of improved APR algorithms. Many algorithms and procedures already exist, including a variety of APR procedures, feature extraction algorithms, digital models of sensor logics, digital filtering techniques, as well as mathematical models that purport to simulate propagation of mechanical waves through layered and nonhomogeneous media. Many of these are of recent development, and have not been adequately validated. The objective of this task is thus to develop an improved set of algorithms and mathetical models of such reliability that they can be used with confidence by the sensor design and military planning communities to predict the performances of existing and conceptual sensors on the battlefield.

Panel III has recently approved this TOR and research plan, and established RSG-11 on APR in Battlefield Surveillance. Three countries are actively participating at present and several more are planning to initiate programs in this area.

2.12 Proposed cooperation on APR in sonar signal processing

As noted above (Section 2.10), Panel III rejected the notion of general cooperation on a mechanical waves program that included both active and passive sonar, and requested a statement from RSG-4 concerning the feasibility of cooperation on APR applied to sonar signal processing. The Ad Hoc Group on Mechanical Waves, which consisted mainly of sonar specialists, discussed this matter in detail at the 12th meeting and again agreed that cooperation is feasible. Moreover, a plan of cooperative research on APR in sonar signal processing was drafted [Annex B to Ref. 22], which consisted of the following elements:

a. Step 1: Creation and exchange of a common data base of sonar signatures. This would provide a uniform standard against which to test various sonar signal processing algorithms. It would also aid in the development of new algorithms.

b. Step 2: Identification, development and testing of appropriate APR algorithms. Participants will individually compile a set of APR algorithms, then share them to form a central listing. Each participant will then be assigned a subset of APR algorithms to apply to the common data base (Step 1, above).

c. Step 3: Evaluation and final report. At the completion of the testing phase, the results will be evaluated by a panel appointed by the participants. The findings of this panel will be presented to Panel III and, it is hoped, would form the basis for the development of more fully automatic APR techniques for sonar signal processing.

This proposal was subsequently presented to Panel III, which shelved the topic pending further discussion. Apparently there is concern at the Panel III level that all of the NATO bodies that are involved with any aspect of sonar should be fully informed about this proposed cooperation prior to taking any action.

2.13 Summary note on proposed cooperative research

The reader will undoubtedly have noted the high degree of communality among the cooperative research proposals developed in the areas of images, speech, battlefield surveillance, and sonar signal processing (Sections 2.8, 2.9, 2.10, 2.11, and 2.12). In effect, the APR specialists in each of these applications areas have said the same thing: before we can perform substantial cooperation in these areas we must (i) have a common data base, <u>or</u> be able to freely transmit data bases among the participating laboratories; and (ii) be able to share existing algorithms and other APR procedures, preferably in digital form using a suitable transfer format.

Stated another way, these specialists are saying: "There is a communication gap in many areas of APR, and international co-operation depends on eliminating this communications gap".

RSG-4 can hardly take credit for this discovery (although, certainly RSG-4 should take credit for awakening the military APR community to the gravity of the situation). Various other groups, including the IEEE, National Bureau of Standards, and Electronic Industries Association AIPR Committee have tried to make the same points for years. Also, there were two panel sessions at the Second International Joint Conference on Pattern Recognition [23,24] which addressed some of these same issues.

The situation is mentioned here primarily because RSG-4 has been subjected to some criticism for having "re-invented the wheel" by listing the same, or a very similar, problem at the outset of proposals for cooperative research in five military applications areas. In conclusion, it is hoped that, by now, everyone is aware of the existing communications gap. International cooperation is only feasible if the gaps can be closed.

2.14 Search for other military APR topics for study

When RSG-4 had scheduled assessments for all the military APR applications originally selected for study (vix., image, speech, and mechanical wave processing), it began to look for "other topics" that should be considered for assessment and/or cooperation. This search for other topics was initiated at the 6th meeting held in August 1974 [11]. Three candidate topics were brought up at the 8th meeting (July 1974): (i) signal processing in general; (ii) robotics; and (iii) interactive processing from the view of man-computer task optimization.

At the 9th meeting (February 1976) [19], five possible topics were discussed:

a. Interactive methods of semi-automatic pattern recognition Earlier, RSG-4 had accepted, but then rejected, this topic for analysis; the final consensus was that most aspects of the topic would more appropriately be covered under the various technology assessments [9, 12, 16]. However, a new aspect of the topic was raised at this meeting: man-machine task optimization.

b. Interactive methods for APR system design. The OLPARS system at Rome Air Development Center [25, 26] had already proven to be a valuable tool for optimizing APR techniques and system design. It was thought that possibly an OLPARS-like facility should be established somewhere in Europe.

c. APR facilities of research laboratories. This would be a catalog of facilities in both participating and nonparticipating countries and laboratories. Another aspect of the topic was the notion of developing a NATO-supported APR research facility somewhere in Europe.

d. Fault detection (all sensors). This involves the general problem of fault detection and anticipation of equipment failures, using all possible sensors (not just acoustic and seismic, as proposed by the Mechanical Waves Group).

e. Microwave processing and signature analysis. This topic included (but was not necessarily limited to) radar signal processing and signature analysis. The topic could have included ECM, although it was generally believed that other NATO bodies were more appropriate for discussions of ECM.

(A word should be injected at this point concerning this search for "other topics" and what would have happened had consensus been reached. One of the reasons why this was such a difficult question is that some of the participating countries did not want to discover any new topics for assessment and/or cooperation. And the reason for that position is really quite simple: they could not afford it. In other words, by this time we had already recommended establishment of a subgroup to prosecute the image processing project, and had two other topics scheduled for assessment for which subgroups would eventually be required. Some of the smaller NATO countries are simply not able to send representatives to an infinite number of NATO groups, regardless of the military significance of a topic.)

At the 10th meeting (November 1976) [20] the responses to the five topics listed above was predictable. Four countries wanted practically all of the new topics incorporated into the work of the three topical subgroups. Two countries were interested in interactive processing, one in APR system design, one in a catalog of facilities, three in fault detection, and two in microwaves. However, there were, in addition, several responses in an area that could be characterized as "multi-sensor pattern recognition" which was, through discussion, elaborated as consisting of several aspects: (i) battlefield surveillance and reconnaissance; (ii) fault detection, quality control, and nondestructive testing; and (iii) medical diagnosis. It was agreed that additional national interests should be surveyed, and that, in addition to these topics, the surveys should also include "artificial intelligence and/or robotics."

Some of the participating countries presented a great deal of information about possible other topics at the 11th meeting [21], so much in fact that it was not possible to reach any consensus at

the meeting; however, some participants were still adamantly opposed to the selection of any new topic for study (see above). There was some discussion about the possibility of organizing a NATO workshop to identify military problems to which APR techniques could be applied. There was also consideration of requesting AC/243 Panel I on Long-Term Scientific Studies to initiate a study. However, these discussions were terminated by Panel III's decision to disband RSG-4.

3. RSG-4 SUBGROUP 1 ON IMAGE PROCESSING (NOW RSG-9)

As previously noted (Section 2.8) the initial proposal for cooperation on image processing was drafted at the August 1974 meeting. Thereafter, the proposal was circulated within the participating countries for comment. The initial meeting of the subgroup on image processing was held in July 1975, at which time the image processing specialists began to plan the conduct of the cooperative tasks. Meanwhile, RSG-4 wrestled with questions about how best to manage the cooperation.

The alternatives considered were: (i) establishment of another RSG; (ii) establishment of an internal subgroup; and (iii) operation under a signed Memorandum of Understanding (MOU). The MOU approach was at first favored by the U. S. because of its visibility and because it would have permitted participation by non-NATO nations. The disadvantages of the MOU approach include the fact that it divorces the project from the NATO group that proposed it, and it requires creation of a separate project management group and structure of the type that already exists under the NATO umbrella (see Section 1). While RSG-4 at first concurred with the MOU approach, Panel III recommended that the cooperative work be conducted by a subgroup established under RSG-4.

3.1 Development of an imagery transfer format

Phase 1 of the cooperative research program on image processing involved reaching agreement on a magnetic tape format to be used in exchanging digitized image data bases among the participating laboratories. Such a format would enable international exchange of image data without necessarily imposing any changeover in image storage format on the laboratories. To exchange data, each laboratory would only have to write two new computer programs, viz., one to transform its data <u>into</u> the transfer format, and another to transform data <u>out of</u> the format.

Preliminary discussions about the transfer format were held at the formative meeting of the image processing subgroup (hereinafter referred to as SG-1) in July 1975. Prior to the 2nd meeting of SG-1

(February 1976) the first draft of a transfer format was circulated [Annex G to Ref. 26]; the discussions at the 2nd meeting then centered around various laboratory hardware and software considerations requiring modification(s) of the proposed format. Minor changes were made as required, and the transfer format was finalized at the 3rd SG-1 meeting in November 1976. This format was subsequently received considerable attention [28, 29] from the pattern recognition community, and is being considered for use as an Electronic Industries Association standard [29].

Table 16 summarizes the characteristics of the SG-1 imagery transfer format. A paper is presently being prepared in which all the details will be presented [30].

Table 16
Characteristics of the SG-1 Imagery Transfer Format

General:

- a. Data is recorded on 1/2 inch wide magnetic computer tape.
- b. Format allows either 7 or 9 tracks at 800 BPI, NRZI.
- c. Maximum record length allowed is 4K tape characters (6 or 8 bits).
- d. A tape contains one or more files.
- e. Files are separated by single EOF marks.
- f. Last file on tape is followed by at least two EOF marks.
- g. A program unit is a program or subroutine or function or card input or output decks.
- h. Each file contains a whole image or one or more program units. Images too large for one tape must be divided into sub-images which are then handled as individual images.
- i. Each file consists of two header records followed by N image data records and N card image records.

Header 1:

- a. The first record of any file (Header 1) is 128 bytes long.
- b. Header 1 is coded in BCD for 7 track tapes, even parity; and in ASC II (Modified) for 9 track tapes, odd parity.
- c. A symbol is recorded in one byte on the tape.

Header 2:

- a. The second record of any file contains a free form description of the image. This may include specification of the physical significance of the various channels, description of scanner, meteorological conditions when image was taken, location of objects of interest in image, etc.
- b. Header 2 has variable length as specified in Header 1(L2). ($0<L2\leq4096$ tape characters.)
- c. Coding is same as Header 1.

(continued)

(Table 16 continued)

d. For source code exchange, Header 2 should contain the name, telephone number and address of the individual responsible for each program unit.
Image Data:
a. Image data is coded in binary, odd parity, one's complement.
b. Integer format is basic to all others.
c. Integer format:
(1) Most significant part is recorded as first tape character.
(2) Most significant bit of first tape character is sign bit (0→positive, 1→negative).
(3) Most significant bit is the left most bit.
d. Real format:
(1) The exponent and mantissa (base 2) are reduced to integers. Both of these are then stored as separate integers on the tape for each sample.
(2) First E_E tape characters for the exponent, then E_m characters for the mantissa.
e. Complex format:
(1) Integer values (T=1) stored as integers.
(2) Real integers (T=3) stored as real values. Each channel consists of two values. The first value is the real part, the second is the imaginary part.
Multichannel Data:
a. Nonregistered data stored as separate images in separate files.
b. Registered data stored on pixel interleaved basis. (For one sample the values of the different channels are recorded adjacently.)

3.2 Documentation of image processing algorithms

Phase 2 of the cooperative program, as originally proposed, consisted of developing a standardized format for documenting existing image processing algorithms, compiling a list of available algorithms, and disseminating the list of standardized documentation among the participating laboratories. The following activities have actually been accomplished under this task:

a. All the participants exchanged representative lists of their computer programs and algorithms.

b. It was determined that a wholesale exchange of image processing algorithms would not be useful (and would be very expensive), because many of the existing algorithms had been written in

assembly language and were very machine dependent. So it was decided not to develop a standardized algorithm description for existing programs. However, a descriptive format may be developed for new programs.

c. Minor modifications were made to the imagery transfer format [29], making it possible to exchange FORTRAN IV source codes. This modified format is described in Ref. 30.

3.3 Assessing national military priorities

Phase 3 of the cooperative program was aimed at conducting such discussions as were required to explore national priorities for achieving military image processing applications and, from the resulting consensus, to derive a prioritized list of topics that could form the basis for substantive cooperative research. Such discussions were conducted at the first three meetings of SG-1. (The national positions are not included in this report.) Four cooperative research projects were drafted as a direct result of these discussions; the first two projects have been approved by Panel III.

3.4 Cooperative research on image processing

3.4.1 Project 1: Discrimination and classification of operating military targets in natural scenes from multispectral data [Annex L to Ref. 20].

a. Data consists of images of operating military targets such as tanks, trucks, ships, planes, etc., received by active reflection or passive emission of visible, IR or microwave radiation. Data to be available in the transfer format [29, 30].

b. Preprocessing includes digitizing, rectification, registration of the images in the several spectral bands and transferring to the transfer format.

c. Goal 1: Discrimination of possible targets from the background. The result will be presented to the operator as a processed image. Possible approaches include multispectral analysis, spatial analysis (e.g., texture analysis).

d. Goal 2: Classification of operating military targets. The results of the processing will be presented as a list of targets.

e. Subgoals to be reached under Goals 1 and 2:

(1) Generation and evaluation of multispectral features for the description of targets and backgrounds.

(2) Generation and evaluation of spatial features (texture, local shape) for the description of targets and backgrounds.

(3) Description of targets and backgrounds based on (1) and (2).

(4) Classification or cueing of targets based on (1), (2) and (3).

(5) Comparison and evaluation of techniques.

(6) Evaluation of the hardware requirements for implementation of the methods.

3.4.2 Project 2: Detection of geographical targets of military relevance from aerial multispectral imagery [Annex M to Ref. 20]

a. Data consists of multispectral images from reconnaissance satellites, airborne sensors, etc.

b. Preprocessing includes digitizing, rectification, registration of the images in the several spectral bands and transferring to the transfer format.

c. Goal 1 is to detect planimetric patterns on the analyzed scene, e.g., roads, railroads, towns, boundaries of lots, industrial plants, air fields, missile sites, and terrain types. Possible approaches include multispectral analysis, texture and shape analysis.

d. Subgoals to be reached:

(1) and (2) Same as Project 1, for ground targets.

(3) Automatic image segmentation based on (1) and (2).

(4) Description of patterns based on (1), (2) and (3) (shape of the pattern, texture, spectral criterion of the surface of the pattern).

(5) Classification of the patterns.

(6) and (7) Same as Project 1 (5) and (6).

3.4.3 Project 3: Tracking of operating military targets in natural scenes from multispectral data [Annex E to Ref. 27].

a. Data consists of images of operating military targets such as tanks, trucks, ships, planes, etc., received by active reflection or passive emission of visible and/or IR radiation. Sequences of frames showing target and/or sensor motion are required. Data should be in the transfer format.

b. Preprocessing is essentially the same as Projects 1 and 2.

c. Goal 1: Target tracking for fire control. Tracking of stationary and/or moving targets from stationary and/or moving platforms by use of an imaging sensor for fire control purposes. Possible approaches include correlation tracking, color tracking, and edge-centroid tracking.

d. Goal 2: Terminal homing for smart ordnance. Tracking of stationary and/or moving targets from a moving missile for the purpose of directing the missile into the target. Possible approaches include same as above plus reticle tracking.

3.4.4 Project 4: Automatic navigation using real time image data [Annex F to Ref. 27].

a. Method: Radar or other EM radiation reflection correlated in very near real time with suitably accessible reference imagery.

b. Data: Real or synthetic images of geographical terrain taken in applicable EM wave band or detailed map data from which such imagery can be synthesized.

c. Preprocessing: Image rectification and scaling, selection of catalog of most readily correlated features, development of map formats (if these are used as reference) in order to convert cartographic data into reference imagery for the purpose of correlation, conversion of polar display to rectilinear format.

d. Goal 1: To achieve success in the preprocessing steps noted above.

e. Goal 2: To generate parameters for auto pilot update.

Projects 3 and 4 (described above in Sections 3.4.3 and 3.4.4) have not yet been approved by Panel III. It should also be noted that, with the termination of RSG-4, Projects 1 and 2 (Sections 3.4.1 and 3.4.2) are being continued by AC/243 (Panel III) RSG-9 on Image Processing.

4. RSG-4 SUBGROUP 2 ON SPEECH PROCESSING (NOW RSG-10)

The first cooperative task proposed by SG-2 on Speech Processing was in the area of voice data entry for command and control. It was agreed that the first two goals of that task should be: (l) to develop specifications and formats for the exchange of speech data bases; and (ii) compilation of a complex matrix relating military applications of voice data entry to the scientific problems involved and the state of the art [31]. The exact nature of the cooperative research on voice data entry would be derived from the conclusions reached in evaluating the matrix.

4.1 Specifications for analog speech tapes

Table 17 summarizes the specifications agreed upon for the exchange of data bases in the form of analog tape recordings [32]. (Formats for digital recordings, algorithm exchange, etc., are to be decided in the future.) This format is being tested by having each country generate a tape recording to be distributed to each other country. The tapes contain the digits, spoken in the project officers' native languages. Evaluation of the tape format is in progress.

Table 17
Specifications for Analog Speech Tapes

1. Reel to reel tapes only; two track.
2. Minimum reel size 5 in (12 cm); maximum 10 in (24.5 cm).
3. No Chromium dioxide tape to be used.
4. Correction or equalization network to be specified.
5. Specify recorder and recorder correction network.
6. Tape speed 7.5 in/sec (19 cm/sec) or 3.75 in/sec (9.5 cm/sec).
7. Spoken header and written specification (date, organization, time, etc.).
8. Reference tone (1000 Hz) after header.
9. Only one track to be used; other track blank.

4.2 Assessment of voice data entry status and priorities

At the second SG-2 meeting (December 1977) a mini-technology assessment was conducted for the specific topic of voice data entry [32]. Table 18 shows the current (i.e., December 1977) ratings of the state of the art in voice data entry in relation to military applications. Note that none of these applications is presently regarded as being solved from a military applications standpoint.

Table 18
Current State of the Art in Voice Data Entry
in Relation to Potential Military Applications

Potential Applications	Rating*
A. Avionic systems	2
1. Query systems	
a. Weather information via voice response	
b. Information retrieval from aircraft instruments	
2. Data entry	
a. Voice input to flight information center	
b. Voice control over instrumentation	
c. Direct voice input to avionic systems	
d. Preparing and arming weapon systems	
e. Changing radio channel frequencies	
f. Preparing flight plans	
B. Interactive Data Handling for Command, Control, Commo	
1. Query systems	3-4
a. Data base query over telephone channels	
b. Inventory control (logistics)	
2. Data entry	3-4
a. Computer input/output	
b. Hands/eyes busy & complete mobility situations	
c. Machine control (semiautomatic assembly)	
d. Remote control (dangerous materials)	
3. Battlefield/tactical data entry	2
a. Information from battlefield to command post	
b. Final control information by front line observer	
4. Maps, charts, photo data entry	3-4
a. Source data capture for generating maps & charts	
b. Aids to photo interpreters & analysts	
5. Simulation for training	2-3
a. Air to air intercept	
b. Cockpit situation simulation	
c. Human operator simulations	
d. Ships maneuvering simulation	

*Ratings: 1 = Early stages of basic investigation
2 = Laboratory investigation
3 = Operational testing
4 = Well in hand
5 = Solved

Table 19 shows the state of the art in voice data entry in relation to desired system capabilities. For this analysis the ratings apply to the general topic, i.e., composed of all of the applications listed in Table 18. Note that no capabilities have been assigned a rating higher than "3" (denoting operational testing).

Table 20 is a matrix which shows the degree to which the capabilities of voice data entry systems are important to the various potential military applications.

Table 21 shows the preliminary consensus about priorities for achieving voice data entry capabilities [32]. These rankings were generated by collapsing across all the national interests expressed at the second SG-2 meeting.

4.3 Cooperative research on voice data entry

Based on an evaluation of the information contained in Tables 18-21, and other national inputs, SG-2 proposed its first substantive cooperative research project which is titled: "Connected-Word Voice Data Entry for Military Command and Control." In Table 20, for example, the connected digit/word capability is rated either 4 or 5 in four of the military applications areas. In Table 21, connected digit recognition was ranked as having the highest priority among the participating countries.

This project aims to overcome the restriction of many present military applications which is that the words must be spoken with pauses between them. It aims to perfect techniques that would permit the digits and a restricted set of command words to be spoken in a connected fashion.

As proposed, the SG-2 participants would synchronize and, in some cases, redirect national efforts toward development of techniques for recognizing connected words. Initial attempts will concentrate on connected digit recognition under laboratory conditions, i.e., using high-quality speech input, etc. After the capability to recognize connected words (digits) has been demonstrated in the laboratory, the project will be broadened to include realistic operational military conditions (telephone bandwidth, etc.). This approach implies that experts think it will be easier to overcome the segmentation problem than the signal quality problem.

At the same time the various ergonomic aspects of military applications will be studied to estimate the benefits accruing from the use of automatic speech recognition, the extent of the problem areas such as poor signals, and the exploitable structures of the tasks leading to techniques such as dynamic sub-vocabulary

Table 19
Current State of the Art in Voice Data Entry
in Relation to System Capabilities

Desired System Capabilities	Rating*
1. Use of task syntax, i.e., dynamic sub-vocabulary selection	3
2. Operation over communication networks, e.g., commercial telephone	2-3
3. Operation in very bad conditions, e.g., tactical radio, secure voice	1
4. Complete spoken numbers connected with a few other words	2-3
5. More general connected sequences of words; limited vocabulary; simple syntax	2
6. Ability to set up for new user without him uttering all the vocabulary words	2
7. Adaptation of speaker to the situation while he is using the system; use of dialogue utterances to improve subsequent recognition	1-2
8. Small size and weight	3
9. Ability to do verification in conjunction with speech recognition	3
10. Prior study of the task (ergonomics, systems analysis, operational)	2

*Ratings: 1 = Early stages of basic invertigation
2 = Laboratory investigation
3 = Operational testing
4 = Well in hand
5 = Solved

Table 20
Degree to Which the Desired Capabilities of Voice Data Entry Systems Are Important to Potential Military Applications

APPLICATIONS \ CAPABILITIES	Task syntax; dynamic selection	Operation over communication networks	Operation in very bad conditions	Spoken digits; a few other words	More general connected words	Ability to train new users	Adaptation to the situation	Small size and weight	Verification with recognition	Ergonomics; systems analysis
Avionic query/entry	4	1	5	5	2-4	2-4	3-4	5	2-3	5
Interactive C^3	4-5	5	2	4	3-5	3-5	3-4	2	4	4
Tactical data entry	4	4-5	5	5	1-5	4	3-5	5	4	5
Graphics data entry	3	2	1	4	3	3-4	3	2	1	3
Simulation	4-5	2	1	3-5	1-5	3-5	3-5	2	1	4-5

Ratings: 1 = not required; 2 = advantageous; 3 = important; 4 = very important; 5 = necessary.

Table 21
Preliminary Consensus About Priorities
for Achieving Voice Data Entry Capabilities

Desired Capabilities	Rank Order*
1. Use of task syntax	3
2. Operation over communication networks	5
3. Operation in very bad conditions	9
4. Recognize connected digits, few other words	1
5. More general connected words	8
6. Ability to train new users	4
7. Situation adaptation	7
8. Small size and weight	6
9. Simultaneous verification & recognition	10
10. Ergonomics; systems analysis	2

*1 = highest priority.

selection will be determined. The applications which will receive the most attention (see Table 18) are voice control of avionic systems and interactive voice data entry for command and control.

In January 1978 Panel III elevated RSG-4 SG-2 to be AC/243 (Panel III) RSG-10 on Speech Processing. The cooperative projects described in this Section are continuing.

5. COOPERATIVE RESEARCH ON APR IN MECHANICAL WAVES

5.1 Battlefield surveillance (RSG-11)

In January 1978, Panel III approved the Terms of Reference of RSG-11 on APR in Battlefield Surveillance. At this writing, however, the national project officers have not been appointed, the number of participating countries is unknown, and no information is available about possible cooperation beyond that presented in Section 2.11.

5.2 Sonar signal processing

The possibility of cooperation on this topic is still being discussed in Panel III; the prospects for establishment of RSG are uncertain. In addition to the problems of data sensitivity, there are internal NATO coordination considerations involved.

6. SUMMARY OF RSG-4'S ACCOMPLISHMENTS

RSG-4 was the first (but, hopefully, not the last) NATO body to undertake any sort of long range study of pattern recognition applications to military problems. As such, it established precedents which will probably guide future activity in this area, particularly if conducted under the auspices of AC/243 Panel III on Physics and Electronics.

This Section merely summarizes the most important things we can point to as accomplishments (products, if you will) of RSG-4's more than six years of existence:

a. A classification scheme for organizing the topic of military applications of APR technology was developed. In 1972 when this was done no other such scheme was in existence.

b. Three iterations of a comprehensive information exchange on PR research project summaries (military and civil) were conducted. The combined summaries were distributed to all identifiable defense researchers and contractors in all the participating countries. This was the first effort of this sort (at least in the U. S.), and it prompted one U. S. researcher to suggest that we should start a cooperative research project among U. S. researchers!

c. Technology assessments of military applications of PR technology to image, speech, and mechanical wave processing were conducted and published as NATO reports. (The speech processing assessment was also published in the open literature.) Each of these assessments summarized the state of the art with respect to military applications, identified the PR techniques that needed to be perfected, and listed the unsolved problems associated with each PR technique. Judging from comments already received from various national defense authorities, these assessments have already been used to determine (in some instances) directions for future military-sponsored research.

d. Cooperative research programs have been established in three applications areas (images, speech, and mechanical waves applied to battlefield surveillance). These programs were at first prosecuted by subgroups established under RSG-4 (in itself, a

rarity) and now, with the conclusion of RSG-4's work, three new RSGs have been constituted to carry out these programs (viz., RSG-9, 10 and 11 under AC/243 Panel III on Physics and Electronics).

e. A transfer format for digitized imagery has been developed and standardized by RSG-4 Subgroup 1 (now RSG-9). This format makes it possible for laboratories to exchange image data bases by writing only two new computer programs: one to transform their data into the transfer format, and another to transform data out of the transfer format. This transfer format has already met with international acclaim, and is being considered for use as a national standard data storage and transfer format.

f. A transfer format has likewise been developed for the exchange of image processing and APR algorithms and procedures.

g. Although relatively intangible, there has been a great increase in the amount of communication among PR researchers, particularly international communication among military PR researchers, as a direct result of the information exchanges and proposals for cooperation developed by RSG-4.

h. An OLPARS-like system [25, 26] was established in the U. K. as a direct result of information exchanged, and technical visits conducted, under RSG-4. U. K. representatives witnessed a demonstration of the OLPARS capabilities during the 4th meeting (November 1973); they requested the software in May 1974, and the final transfer of system software took place at the 12th meeting in November 1977.

7. WHAT RSG-4 FAILED TO ACCOMPLISH

RSG-4 failed to accomplish any sort of information exchange, assessment or cooperation directly related to the human factors aspects of military APR applications. Despite the fact that all APR applications to complex problems in both military and civil situations presently involve man-machine interaction, and despite the fact that such is likely to be the case for the foreseeable future, no sustained interest could be generated among the majority of the RSG-4 delegates to consider the human factors aspects of APR applications in any separate and systematic fashion. This fact seems particularly ironic in view of the fact that two countries (Netherlands, and U. S.) appointed delegates to RSG-4 who had backgrounds in computer science and human factors engineering, for the express purpose of injecting some human factors consideration into the work of RSG-4.

This unwillingness to consider the human factors aspect may be illustrated by an incident that occurred early in the deliberations

of SG-1. The first proposal for cooperative research on detection of operating military targets gave as one of the purposes the "cueing of operators". But the proposal included no procedure for determining that the operator had, in fact, been cued! This was pointed out, and the proposal's author stated that he was interested only in image processing, not in operator cueing. As a result, the final version of the project statement (Section 3.4.1) makes only an oblique reference to operator cueing and does not cite it as one of the goals of the project.

It would, however, only be fair to make two additional points in this regard. First, the other five national delegates to RSG-4 had no background in human factors and little interest in those aspects of APR applications; thus, they would probably have felt out of place trying to deal with such problems. Secondly, some sentiment was expressed to the effect that the human factors aspects of APR applications should be treated by RSG-5 on Human Engineering (which was later elevated to become AC/243 Panel VIII on Human and Biomedical Sciences [33]). In fact, due to the communality of interest in pattern recognition problems between RSG-4 and RSG-5, liaison was established at the national level to keep RSG-5 informed about RSG-4 activities. However, RSG-5 did not then have any working groups addressing topics relevant to APR, nor does Panel VIII have any such groups at this time.

The closest that RSG-4 came to addressing any of the human factors aspects of APR applications was in its search for other topics for study (see Section 2.14). One of the possible topics that was discussed was "Interactive Methods of Semi-Automatic Pattern Recognition", which was elaborated to include man-machine task optimization. Task optimization has recently received considerable attention [34-37]. In order to optimize the design of a pattern recognition system, one has to be able to define the capabilities of both the human and the machine components; then, presumably, one can configure a system for a particular application that will make the best use of the components' capabilities and limitations. However, consideration of this topic was cut short by Panel III's decision to disband RSG-4.

8. PROSPECTS FOR FUTURE NATO PATTERN RECOGNITION ACTIVITY

AC/243 (Panel III) RSG-4 on Automatic Pattern Recognition was disbanded by Panel III at its January 1978 meeting [38]. This major scientific information exchange and technology assessment program, whose activities spanned more than six years, has ended. But in its place, three new RSGs continue to function: (i) RSG-9 on Image Processing; (ii) RSG-10 on Speech Processing; and (iii) RSG-11 on Automatic Pattern Recognition in Battlefield Surveillance with

Mechanical Waves. In one sense, then, future NATO activity in the area of pattern recognition is virtually assured for the next five years.

The main question, however, is: "What are the prospects for NATO getting involved in other pattern recognition applications in the future?"

One of the factors that will have to be considered is the degree of support that the smaller nations may be willing or able to provide. The smaller NATO nations cannot afford to participate in an infinite variety of groups. Thus, one requirement for further NATO pattern recognition activity will be identification of an application that is so important it will cause nations to reorder their priorities.

Another factor governing future activity will be a determination of the most appropriate NATO body to serve as a forum. At present, Panels III and VIII appear to be the most likely candidates; but other choices should probably be considered. The matters discussed in Section 7 may also be relevant here.

For the immediate future (next five years) NATO pattern recognition activity will probably be confined to RSGs 9, 10 and 11. After that Panel I should probably be petitioned to initiate one of its long-term study programs.

REFERENCES

1. U. S. Army Regulation 34-1. Standardization: United States Participation in NATO Military Standardization Research, Development, Production, and Logistic Support of Military Equipment. Headquarters, Department of the Army, Washington, D. C., 5 April 1974.
2. AC/243 (Panel III) Document 115. Report of the Ad Hoc Group on the Military Applications of Millimeter Waves. NATO Headquarters, Brussels, Belgium, 28 June 1974.
3. D. C. Hodge. Automatic Pattern Recognition: Defense Research Projects in Seven NATO Countries. Report RSG-4-1A, July 1972. (Available only from U. S. Defense Documentation Center, Alexandria, Va.: AD905384L.)
4. D. C. Hodge & E. J. Simmons. Automatic Pattern Recognition. Report RSG-4-2A, June 1973. (Available only from U. S. Defense Documentation Center, Alexandria, Va.: AD914008L.)
5. D. C. Hodge & H. E. Webb. Automatic Pattern Recognition Research in the United States. Part 1: Department of Defense Supported Projects (Unclassified; Unlimited). Part 2: Projects Supported by Other Sources. Report RSG-4-3A, September 1976.

6. D. C. Hodge & H. E. Webb. Automatic Pattern Recognition. Part 3: Projects Conducted by Countries Other Than the United States. Report RSG-4-3A, December 1976.
7. E. J. Simmons, Jr. A Summary of Expressions of Interest in International Workshops in the Area of Automatic Pattern Recognition. Presented to NATO AC/243 (Panel III) RSG-4, May 1973.
8. Unpublished Minutes of 5th RSG-4 meeting, November 1973.
9. An Assessment of the Technology of Automatic Image Processing for Military Purposes. Annex G to Minutes of 7th RSG-4 meeting, August 1974.
10. D. C. Hodge. NATO RSG-4 on Pattern Recognition: Proposed Cooperative Research on Image Processing. In L. N. Kanal (Ed.), Proceedings of EIA-NSF Workshop on Near Future Prospects in Image Pattern Recognition. Silver Spring, Md., 1975, pp. 157-163.
11. Unpublished Minutes of 6th RSG-4 meeting, May 1974.
12. AC/243 (Panel III/RSG.4) Document 13. An Assessment of the Technology of Automatic Speech Recognition for Military Applications. NATO Headquarters, Brussels, Belgium, 13 April 1976.
13. B. Beek, E. P. Neuberg, & D. C. Hodge. An Assessment of the Technology of Automatic Speech Recognition for Military Applications. IEEE TRANSACTIONS on Acoustics, Speech, & Signal Processing, 1977, vol. ASSP-25, 310-322.
14. D. H. Klatt. Review of the ARPA Speech Understanding Project. J. Acoust. Soc. Amer., 1977, 72, 1345-1366.
15. Unpublished Minutes of 7th RSG-4 meeting, August 1974.
16. AC/243 (Panel III/RSG.4) Document 15. An Assessment of the Technology of Automatic Processing of Signals Due to Mechanical Waves in Solids, Liquids and Gases for Military Purposes. NATO Headquarters, Brussels, Belgium, 15 March 1977.
17. EIA Committee on Automatic Imagery Pattern Recognition. 5th Annual Symposium, College Park, Md., April 1975.
18. R. Franke. The Specification of Algorithms. Technical Report, U. S. Naval Postgraduate School, Monterey, Calif., July 1975. AD A013564.
19. Unpublished Minutes of 9th RSG-4 meeting, February 1976.
20. Unpublished Minutes of 10th RSG-4 meeting, November 1976.
21. Unpublished Minutes of 11th RSG-4 meeting, June 1977.
22. AC/243 (Panel III/RSG.4). Final Report of RSG-4 to Panel III. NATO Headquarters, Brussels, Belgium, in press. (Submitted December 1977.)
23. L. N. Kanal (Chm.). Panel on General and Dominant Problems in Pattern Recognition. 2nd International Joint Conference on Pattern Recognition, Lyngby, Denmark, August 1974.
24. D. H. Foley & H. L. Oestreicher (Chm.). Panel on Bridging the Gap Between Pattern Recognition Theory and Practice, With Particular Emphasis on Representative Data Bases. 2nd International Joint Conference on Pattern Recognition, Lyngby, Denmark. August 1974.

25. J. Faust, H. Webb, & L. Gerhardt. RADC Interactive Laboratory for Design of Pattern Recognition, and Its Function. Proceedings of the Conference on Computer Graphics, Pattern Recognition and Data Structures, May 1975. IEEE Catalog No. 75CH0981-1C.
26. Pattern Analysis & Recognition Corp. Multics OLPARS Operations System, Vol. 1. Technical Report 76-271, Rome Air Development Center, Griffiss Air Force Base, N. Y., 1976.
27. Unpublished Minutes of 2nd RSG-4/SG-1 meeting, February 1976.
28. J. M. Evans, Jr., R. Kirsch, & R. N. Nagel (Eds.). Proceedings of Workshop on Standards for Image Pattern Recognition, held in Gaithersburg, Md., 3-4 June 1976. National Bureau of Standards Special Publication 500-8, May 1977.
29. J. S. Dehne. Proposed EIA Standards for Digital Imagery on Magnetic Tape. Paper presented to 7th Annual Symposium of EIA Committee on Automatic Imagery Pattern Recognition, College Park, Md., May 1977.
30. J. S. Dehne. NATO Transfer Format for Digitized Imagery and Source Codes. In preparation for submission to Pattern Recognition, 1978.
31. Unpublished Minutes of 1st RSG-4/SG-2 meeting, June 1977.
32. Unpublished Minutes of 2nd RSG-4/SG-2 meeting, December 1977.
33. AC/243 (Panel VIII) Document 1. Report to the DRG by the Chairman of Panel VIII. NATO Headquarters, Brussels, Belgium, 9 October 1974.
34. E. C. Poulton. Experiments on Detection and Classification with the Assistance of a Computer. Report No. DRIC-BR-48925, Royal Naval Personnel Research Committee, March 1974. AD A019314.
35. C. D. Wylie, R. A. Dick, & R. R. Mackie. Toward a Methodology for Man-Machine Function Allocation in the Automation of Surveillance Systems. Vol. I: Summary. Human Factors Research, Inc., Goleta, Calif., 1975. AD A017013.
36. D. A. Topmiller. Man-Machine Command-Control-Communication Simulation Studies in the Air Force. Technical Report 76-122, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, 1976. AD A042148.
37. B. M. Crawford, D. A. Topmiller, & G. A. Kuck. Man-Machine Design Considerations in Satellite Data Management. Technical Report 77-13, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, 1977. AD A041287.
38. AC/243 (Panel III) Document 159. Draft Terms of Reference for New Research Study Groups. NATO Headquarters, Brussels, Belgium, 6 February 1978.